Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

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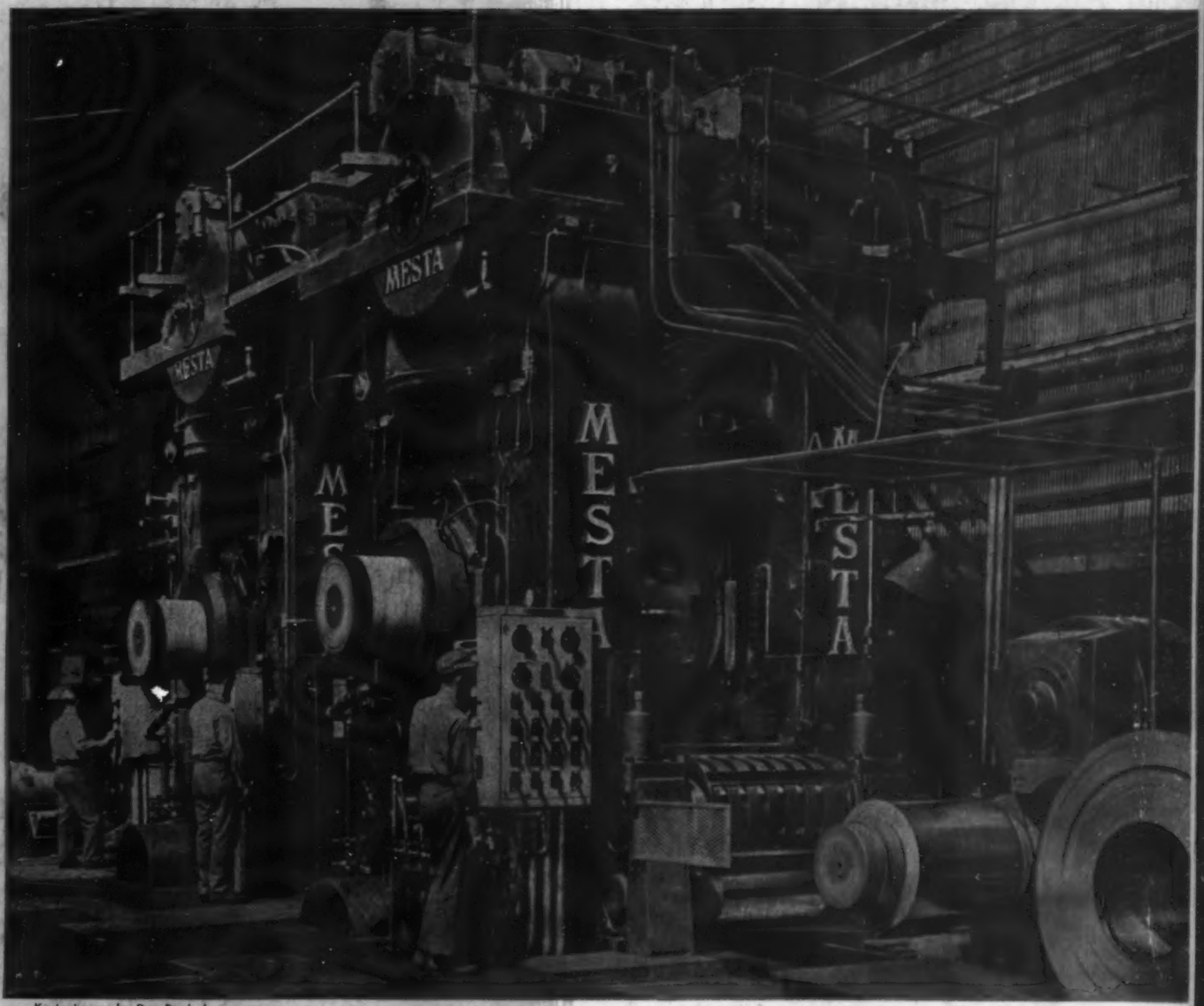
AUGUST, 1947

PUBL... SEP 3 1947 ...ETROIT

...CHNOLOGY DEPARTMENT

MESTA *Cold Mills*

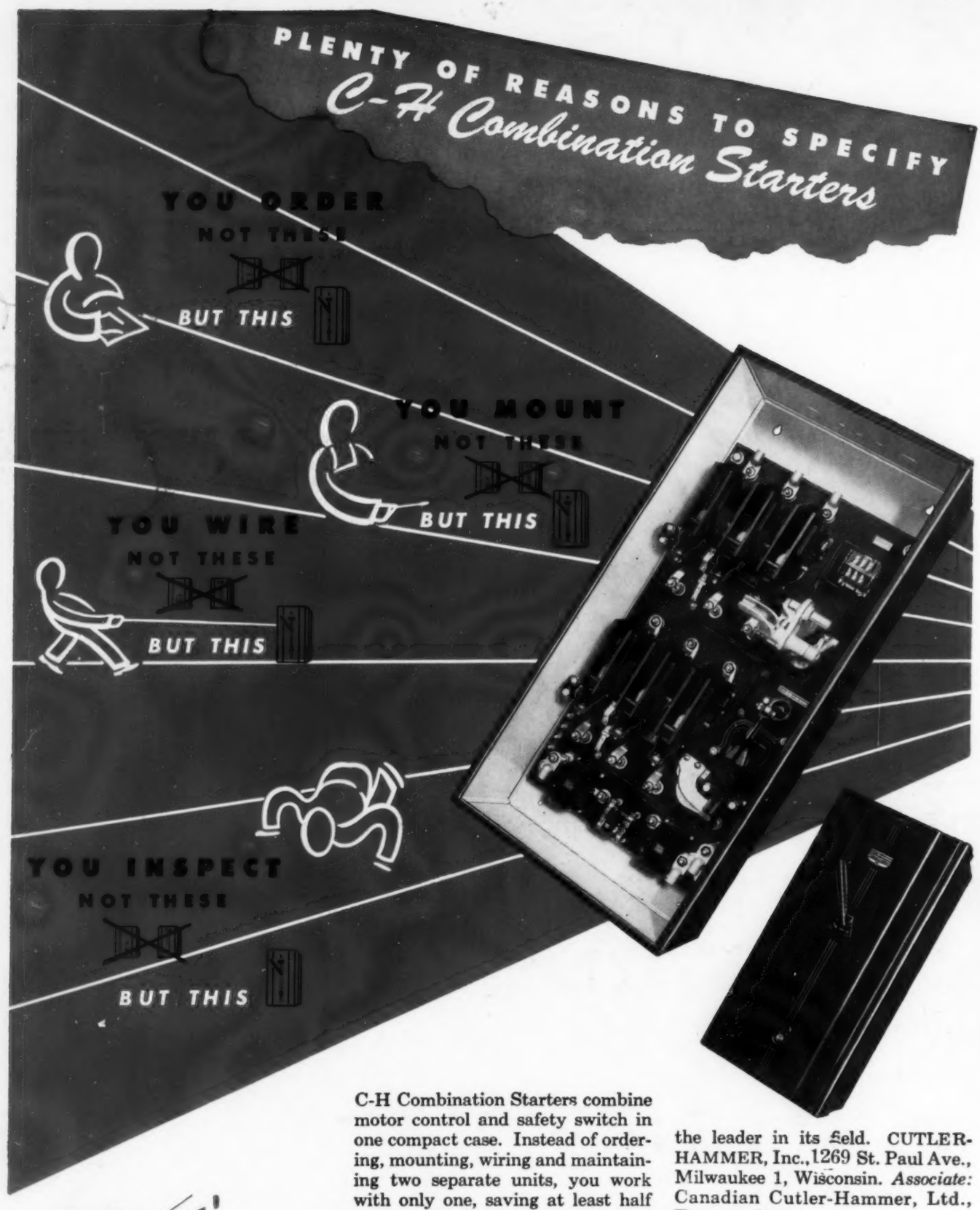


Kodachrome by Dan Reebel

All required tempers can be produced on Mesta High-Speed Twin Four-High Cold Skin Pass Mills. These mills feature new types of drives and control systems which maintain synchronization during acceleration, deceleration, and at normal operating speeds.

DESIGNERS AND BUILDERS OF COMPLETE STEEL PLANTS.

MESTA MACHINE COMPANY . . . PITTSBURGH, PA.



PSST!

YOU ALSO SAVE SPACE

C-H Combination Starters combine motor control and safety switch in one compact case. Instead of ordering, mounting, wiring and maintaining two separate units, you work with only one, saving at least half the installation time, saving on conduit, wire and fittings, saving in space, saving inspection and maintenance time and trouble. In addition, you get world-famous C-H eutectic alloy overload relay protection, dust-safe vertical contacts, many other important features that have established the C-H unit as the leader in its field. CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ont.

CUTLER-HAMMER
MOTOR CONTROL
C-H

IRON AND STEEL ENGINEER, published monthly by Association of Iron and Steel Engineers, entered as second class matter January 25, 1924 at Pittsburgh, Pennsylvania, under Act of Congress, March 3, 1879. $7.50 per year in United States, $8.25 Canada, $10.00 foreign countries. Volume 24, No. 8.

A E T N A · S T A N D A R D

did you ever see a
MULTIPLE SLITTING & SIDE TRIMMING LINE
with all these innovations?

COIL UNLOADING DEVICE

This coil unloading device permits unloading of one strand or more as desired. Installed at tension reel, the unloader saves many hours of handling time . . . fast, efficient, and compact.

1

TENSION REELS

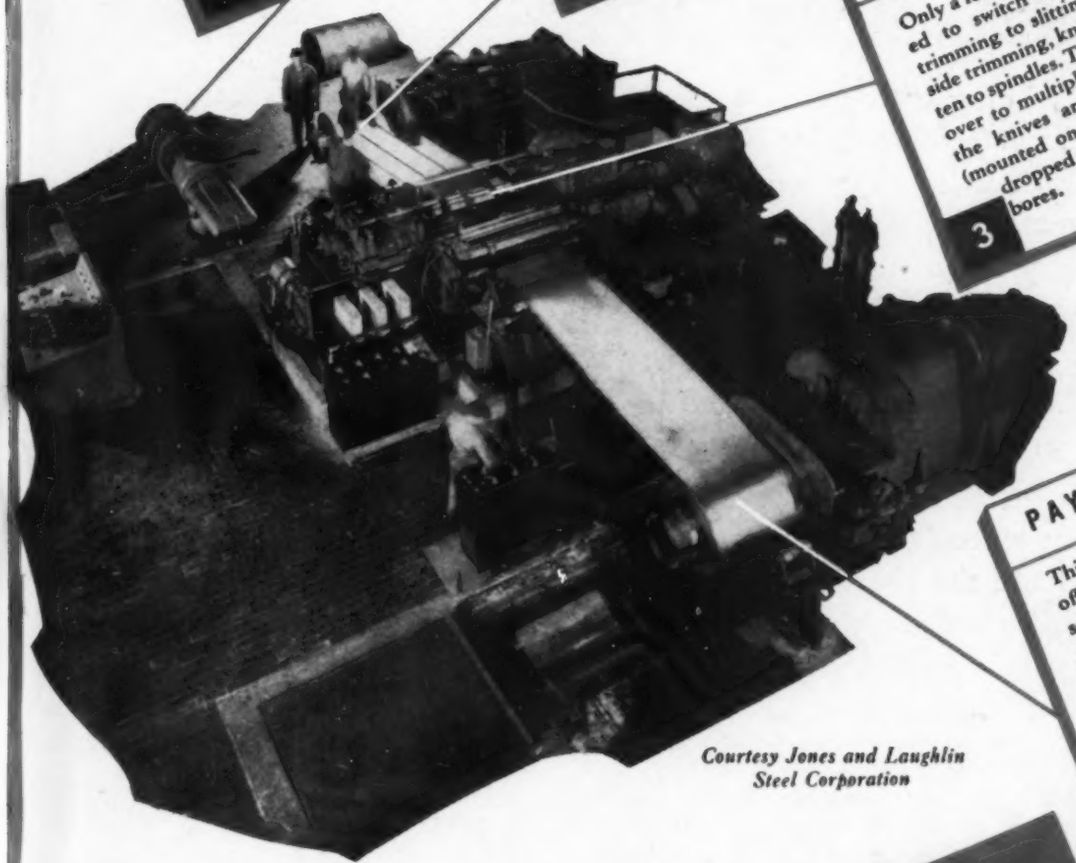
Here's something new in tension reels. Coils of 16" I. D. and 20" I. D. are handled with the Aetna-Standard tension reel on this line.

2

QUICK SWITCH-OVER

Only a few minutes needed to switch from side trimming to slitting. For side trimming, knives fasten to spindles. To change over to multiple slitting, the knives and spacers, (mounted on arbors) are dropped into tapered bores.

3



Courtesy Jones and Laughlin Steel Corporation

PAY-OFF REEL

This mandrel-type pay-off reel, with removable segments, handles 3 sizes of coils . . . 20" - 24" - 30" dia. Here again, many hours production time can be gained in change-over operations.

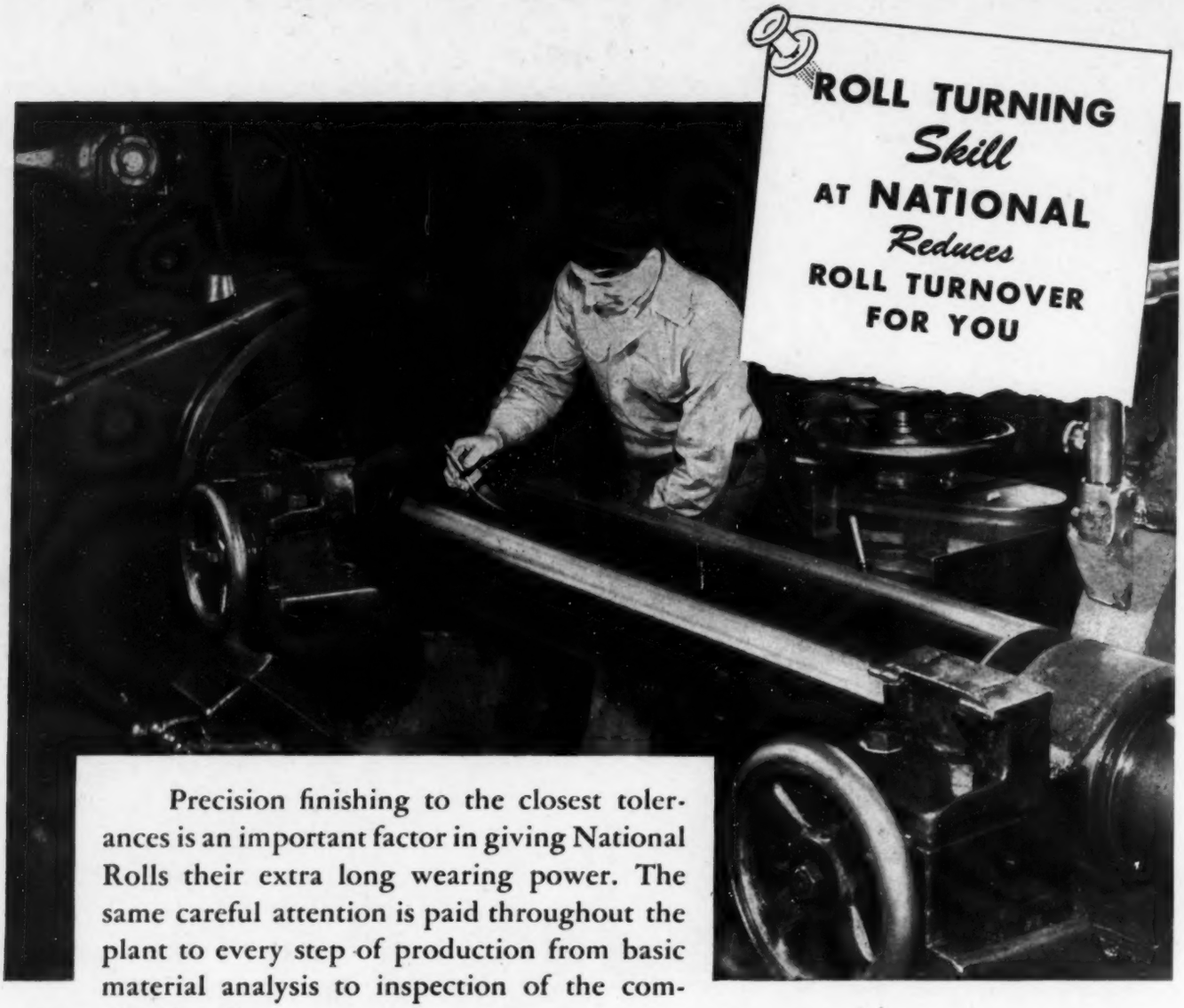
4

Sizes—Side Trimming and Multiple Slitting cold reduced coils up to 48" max. in gauges .017 to .109. *Max. Wt.*—22,000 lbs. *Speeds*—250 to 1,000 ft. per min. *Advantages*—(a) fast handling; (b) easy threading and operating; (c) quick unloading; (d) more production time—less man hour waste.

In addition to the four major innovations, this line has many other unique features. And Aetna-Standard sales engineers, upon request, will be glad to discuss your requirements.

THE AETNA-STANDARD ENGINEERING CO.
YOUNGSTOWN, OHIO

ASSOCIATED COMPANY:
HEAD, WRIGHTSON & CO., LTD., THORNABY-ON-TEES, ENGLAND



Precision finishing to the closest tolerances is an important factor in giving National Rolls their extra long wearing power. The same careful attention is paid throughout the plant to every step of production from basic material analysis to inspection of the completed roll.

This care in manufacture is reflected in the inherent strength and durability of National Rolls.

With recent extensive additions to the plant completed and the installation of more new roll finishing machines, National is now able to supply your iron and alloy iron roll requirements better than ever.

National Rolls

THE NATIONAL ROLL & FOUNDRY CO.
AVONMORE, PENNSYLVANIA

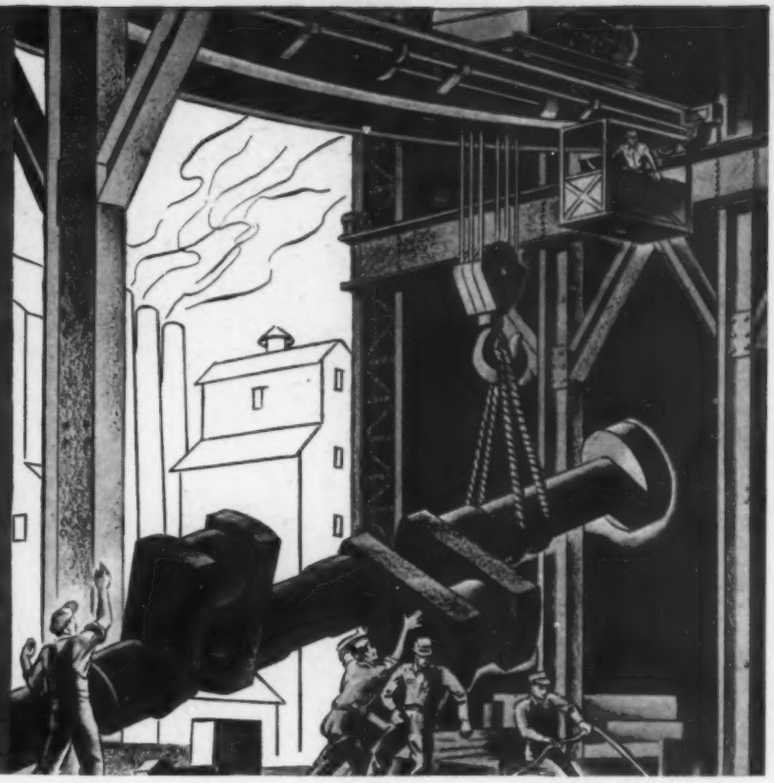
for Cranes--

as well as for your car

Hydraulic Brakes are Best

only **Wagner**

HYDRAULIC CRANE BRIDGE BRAKES give you these *Features*



• Two Types—Four Sizes—Cover the Field

Wagner hydraulic brakes for overhead traveling cranes and other industrial equipment are built with or without parking attachment, in four sizes that cover the entire range of bridge brake applications—light industrial cranes, high speed steel mill cranes, even the largest steel mill ladle crane.

• The New Remote Control Bleeder—

Makes bleeding the hydraulic system a "one-man one-minute" job. Keeps lines full of fluid, maintains peak braking efficiency . . . solves problem of ladle crane applications.

• The New Self-Centering Design

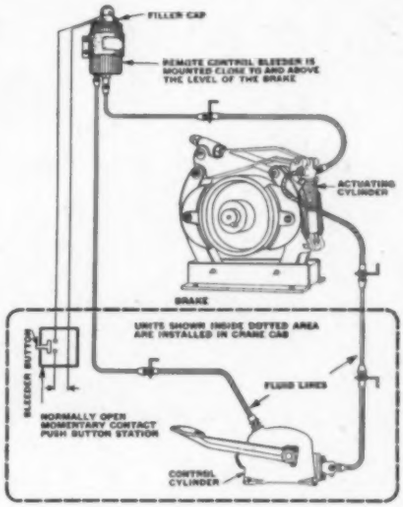
Assures equal clearance of both brake shoes, prevents brake shoe drag. Other advantages include: power failure braking . . . one-point shoe adjustment . . . 200% emergency torque . . . grease fittings for lubrication . . . non-scoring, easily replaced molded lining blocks.

• New Systems Easy to Install

If your cranes are not equipped with Wagner hydraulic brakes, let one of our field engineers show you how simple it is to install the modern system you need. All Wagner systems now include the remote control bleeder.

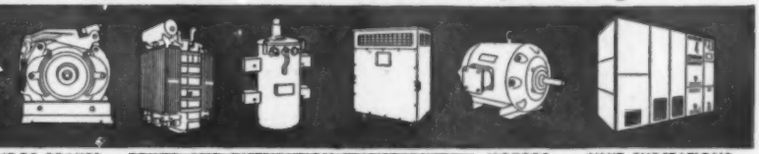
• Old Systems Easily Modernized

You can bring your present Wagner system up-to-date with our complete-to-the-last fitting conversion kits. You can change your old solenoid-controlled HM brake to the new, compact hydraulic-released type; you can convert a type H brake to an HM; and you can easily add the new remote control bleeder to any Wagner system. Write for Bulletin IU-186 on Wagner Industrial Brakes. Wagner Electric Corporation, 6483 Plymouth Avenue, St. Louis 14, Mo. U. S. A.


FILLER CAP
REMOTE CONTROL BLEEDER IS MOUNTED CLOSE TO AND ABOVE THE LEVEL OF THE BRAKE
ACTUATING CYLINDER
BRAKE
UNITS SHOWN INSIDE DOTTED AREA ARE INSTALLED IN CRANE CAB
BLEEDER BUTTON
FLUID LINES
NORMALLY OPEN MOMENTARY CONTACT PUSH BUTTON STATION
CONTROL CYLINDER

Consult Wagner Engineers on all Crane-Bridge Braking Problems

Wagner Electric Corporation
EST. 1891

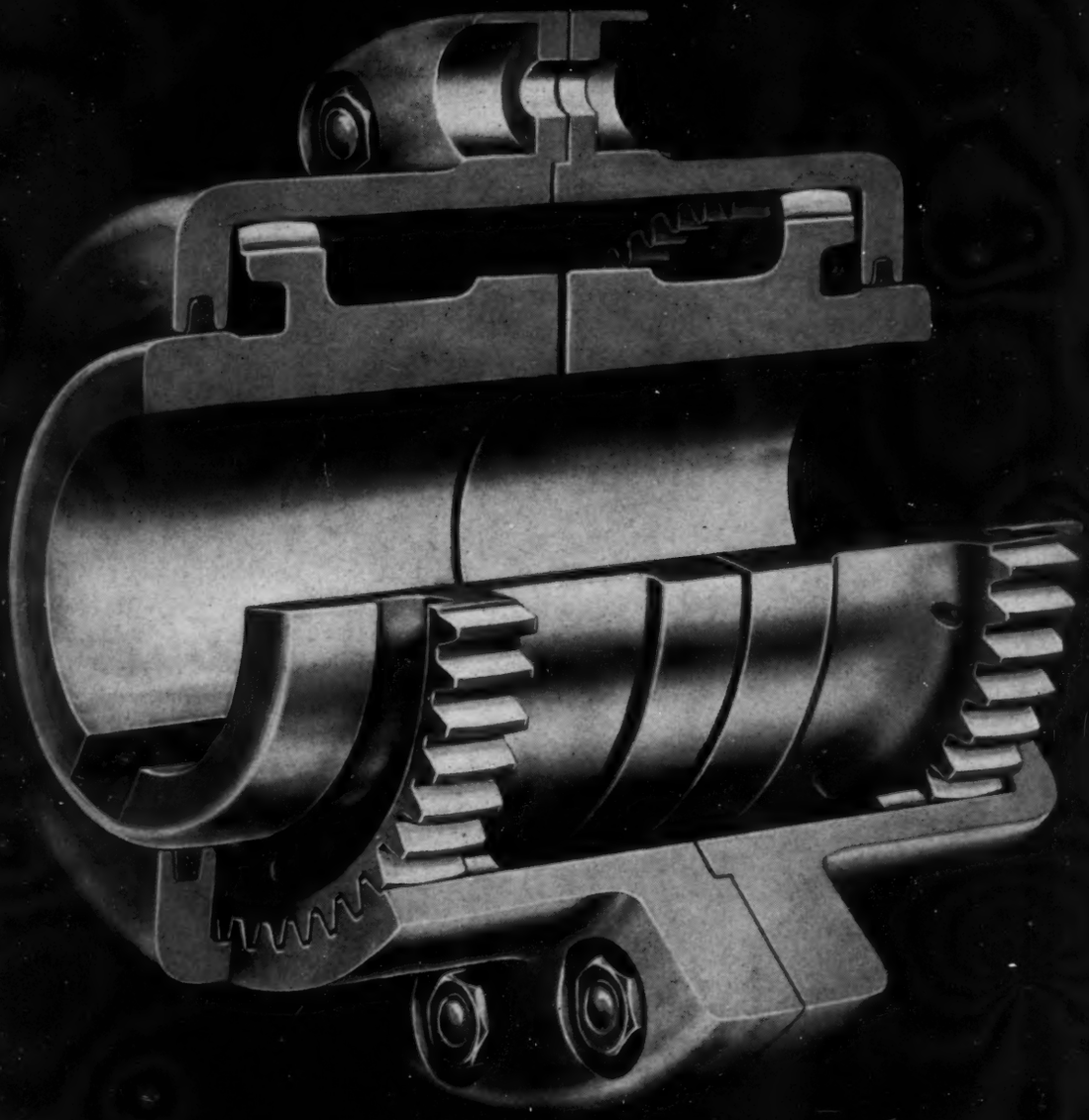


147-5

BRIDGE BRAKES • POWER AND DISTRIBUTION TRANSFORMERS • MOTORS • UNIT SUBSTATIONS

ELECTRICAL AND AUTOMOTIVE PRODUCTS

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

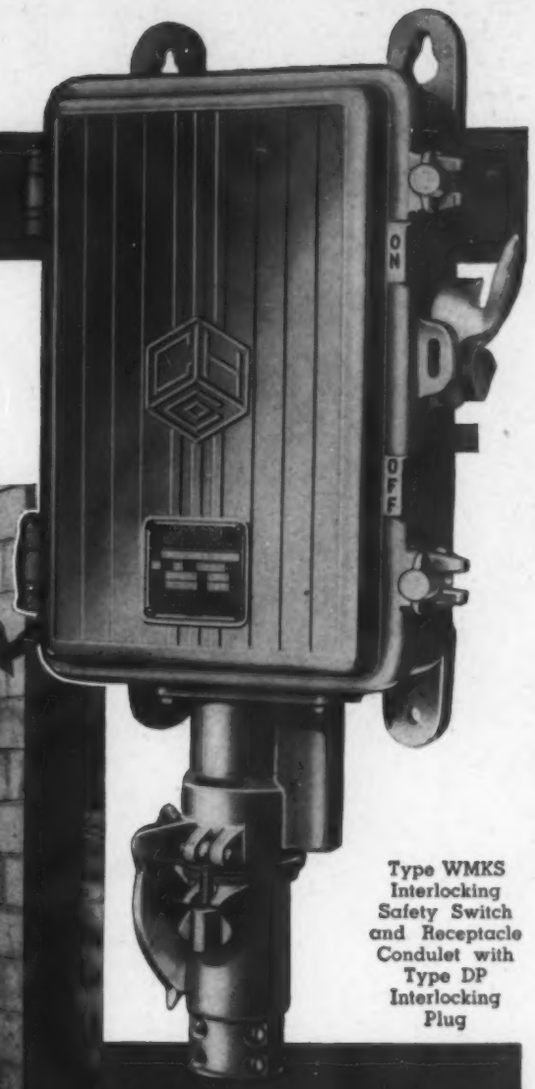
POOLE FOUNDRY & MACHINE COMPANY

WOODBERRY, BALTIMORE, MD.

Type WMKS **Interlocking** Safety Switch and Plug Receptacle

CONDULET*

for the control of all kinds of
portable electrical equipment
in both indoor and outdoor locations



Type WMKS Interlocking Safety Switch and Receptacle Conduclet with Type DP Interlocking Plug

It's heavy duty!
It's raintight!

Safety. Positive interlock prevents opening the case or withdrawing the plug unless the switch is "off". Switch can't be turned "on" unless the case is closed and the plug fully inserted.

Switches. Motor circuit switch. Quick make and break. Double break, reinforced, positive pressure-type blade and jaw construction. Positive pressure fuse clips. Combination solder or solderless wire lugs. 2 or 3-pole fusible.

Plug Receptacles. Style 1 is grounded through the shell of the plug and the receptacle housing. It will take the plugs used with the former Type MKS of the same rating. Style 2 is grounded through an extra pole and the shell. An eyebolt and wingnut prevents accidental withdrawal of the plug when the switch is open.

Cast metal case. Strong and durable. Four sturdy mounting feet. Many possible threaded hub arrangements for both vertical and horizontal conduit. Cover may be padlocked to prevent unauthorized entry. Operating handle may be padlocked "on" or "off".

Threaded operating shaft. Bearings permanently lubricated to resist corrosion and prevent the entrance of dust and moisture.

Horse-power ratings. 2 through 50 H. P. 30, 60, 100 or 200-ampere. 230 or 575-volt A. C.

Listed in Conduclet Catalog 2500, Section 50.

*CONDULET is a coined word registered in the U. S. Patent Office. It designates a product made only by the Crouse-Hinds Company.

Our 50th Anniversary
1897 — 1947

A Nationwide Distribution Through Electrical Wholesalers

CONDULETS
FLOODLIGHTS
TRAFFIC SIGNALS
AIRPORT LIGHTING

CROUSE-HINDS COMPANY
Syracuse 1, N. Y.

Offices: Birmingham – Boston – Buffalo – Chicago – Cincinnati – Cleveland – Dallas – Denver – Detroit – Houston – Indianapolis Kansas City – Los Angeles – Milwaukee – Minneapolis – New York – Philadelphia – Pittsburgh – Portland, Ore. – San Francisco Seattle – St. Louis – Washington. *Resident Representatives:* Albany – Atlanta – Charlotte – New Orleans – Richmond, Va. CROUSE-HINDS COMPANY OF CANADA, LTD., *Main Office and Plant:* TORONTO, ONT.

Photograph of High Tensile Manganese Bronze Screw Nut for 4 Hi Roll Stand on Hot Strip Mill. Rough Weight—2400 pounds.

N·B·M
SCREW-DOWN NUTS
stress and shock resistant

Special dense alloys of high-tensile manganese bronze, aluminum bronze, and hydraulic bronze—perfected by painstaking Brake Shoe Research—give N-B-M Screw-Down Nuts the strength to maintain constant roll pressure under constant battering. You will be sure of longer trouble-free service, if you specify

N·B·M BRONZE AND COPPER CASTINGS

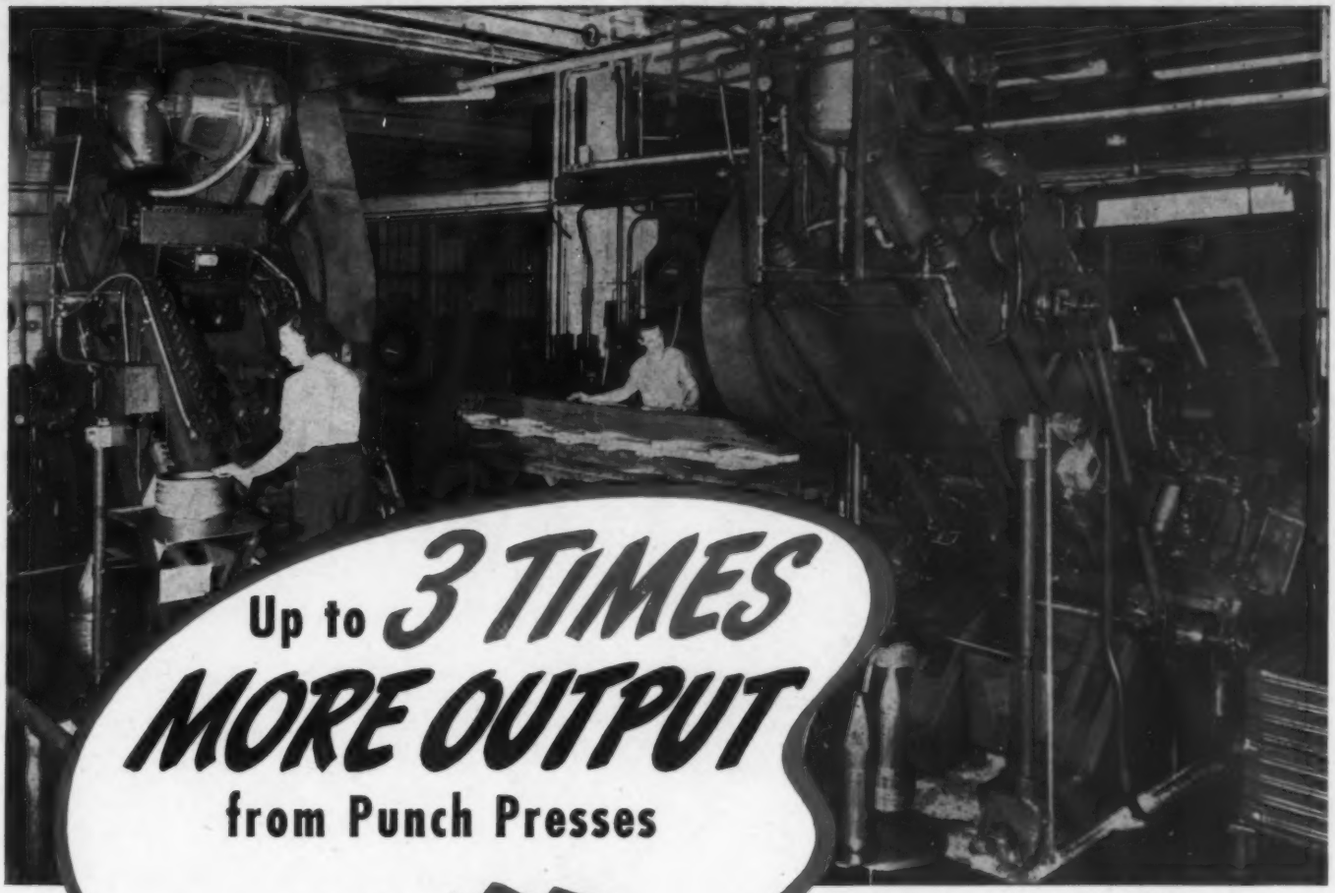
Blast Furnace Copper Castings • Roll Neck Bearings • Slippers • Housing Nuts Machinery Castings • Babbitt Metals • Acid Resisting Castings • Phosphorized Copper

NBM

AMERICAN Brake Shoe COMPANY

NATIONAL BEARING DIVISION
PITTSBURGH • NEW YORK

PLANTS IN: ST. LOUIS, MO. / PITTSBURGH, PA. / JERSEY CITY, N. J. PORTSMOUTH, VA. / ST. PAUL, MINN. / CHICAGO, ILL.



Up to 3 TIMES MORE OUTPUT from Punch Presses

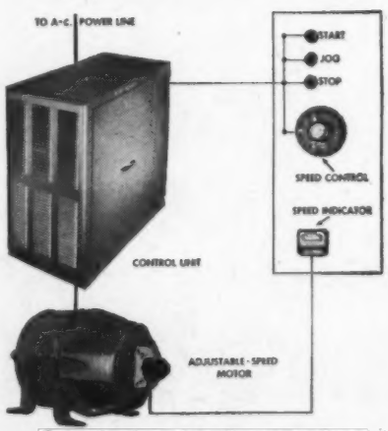
...with RELIANCE V★S DRIVE

With repeat-stroke operation, V★S makes possible 2 to 3 times greater production by providing adjustable speeds to suit a variety of materials and operating conditions.

Don't miss the Operating Exhibit of RELIANCE V★S DRIVE SPACE 302-C at the MACHINE TOOL BUILDERS SHOW CHICAGO, SEPT. 17th THRU SEPT. 26th

Reliance V★S Drive makes it possible to adjust machine speed to assure maximum production at the turn of a rheostat knob. Quick, smooth starts and stops—inching speeds for setting up—and remote control are other V★S contributions to efficiency and safety in processing equipment.

V★S, the *All-electric, Adjustable-speed Drive operating from A-c. Circuits,* has a record of improving quantity and quality of production while lowering costs on *every* type of machine on which it has been used. We suggest you write today for reprint of article, "Variable-Speed Jumps Output" and Bulletin 311.



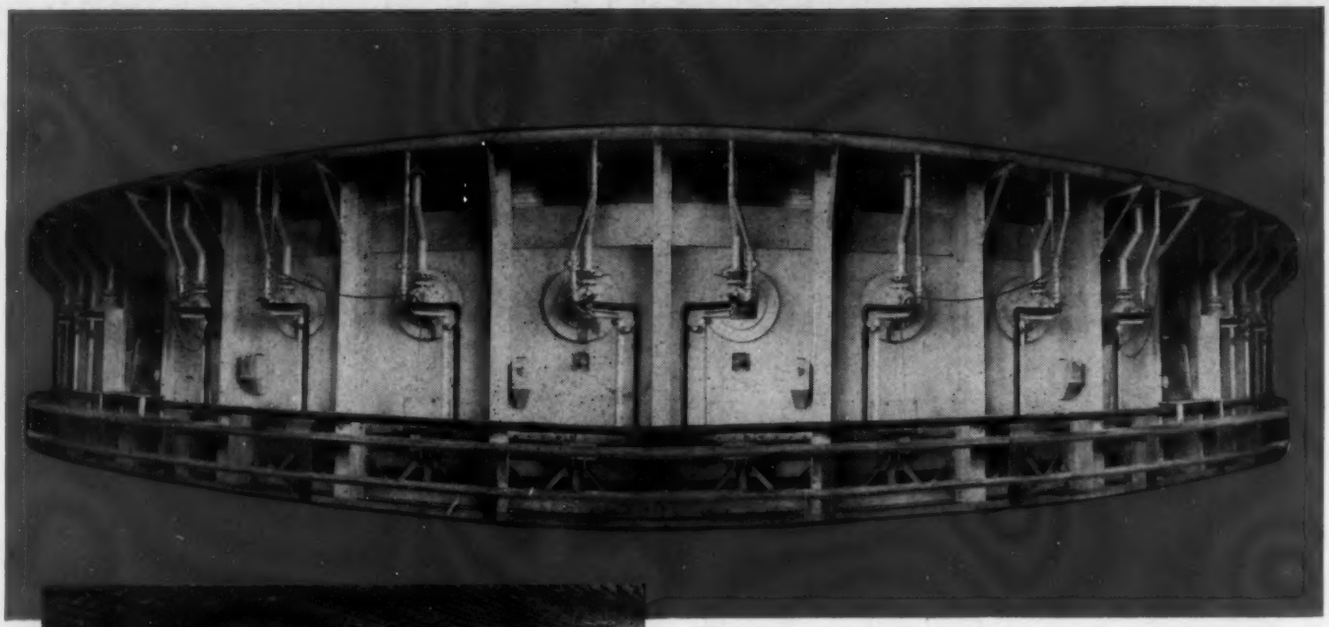
Conveniently-packaged, space-saving V★S Drives are available from 1 to 200 hp.

RELIANCE ELECTRIC & ENGINEERING CO.
1084 Ivanhoe Road • Cleveland 10, Ohio

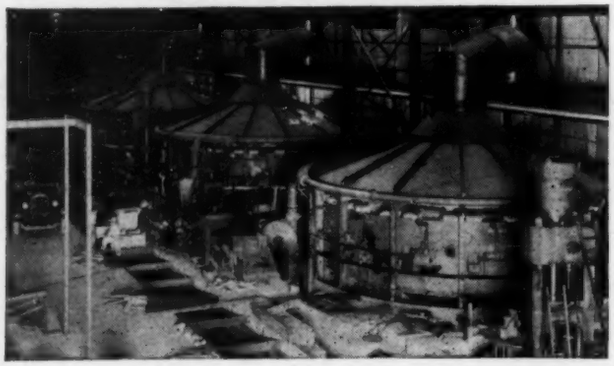
Appleton, Wis. • Birmingham • Boston • Buffalo • Chicago • Cincinnati • Dallas • Denver • Detroit • Gary Grand Rapids • Greenville, S. C. • Houston • Kansas City • Knoxville • Los Angeles • Milwaukee Minneapolis • New Orleans • New York • Philadelphia • Pittsburgh • Portland, Ore. • Roanoke, Va. Rockford • St. Louis • San Francisco • Seattle • Syracuse • Tampa • Tulsa • Washington, D. C. Sao Paulo, Brazil

RELIANCE A-C D-C MOTORS

"Motor-Drive is More Than Power"



Inside view after five years' service.



WHY THE WORLD'S LARGEST ROTARY FURNACES ARE SALEM BUILT

On rotary hearth furnaces, hearth alignment—maintained concentric with the furnace chamber—is an important contributing factor to long life and good performance of the equipment.

Salem recognized this fact long ago, and accordingly our engineers developed a special patented feature which is now included on all Salem rotary furnaces. As a result of this new development, the Salem hearth rotates true about adjustable guide rollers, like the outer race of a roller bearing. Complete details and information are available on request.

SALEM ENGINEERING CO. · SALEM, OHIO
SOUTHWEST OFFICE · FORT WORTH, TEXAS
SALEM ENGINEERING CO. (Canada) Ltd., TORONTO
SALEM ENGINEERING CO. LTD., SHEFFIELD, ENGLAND

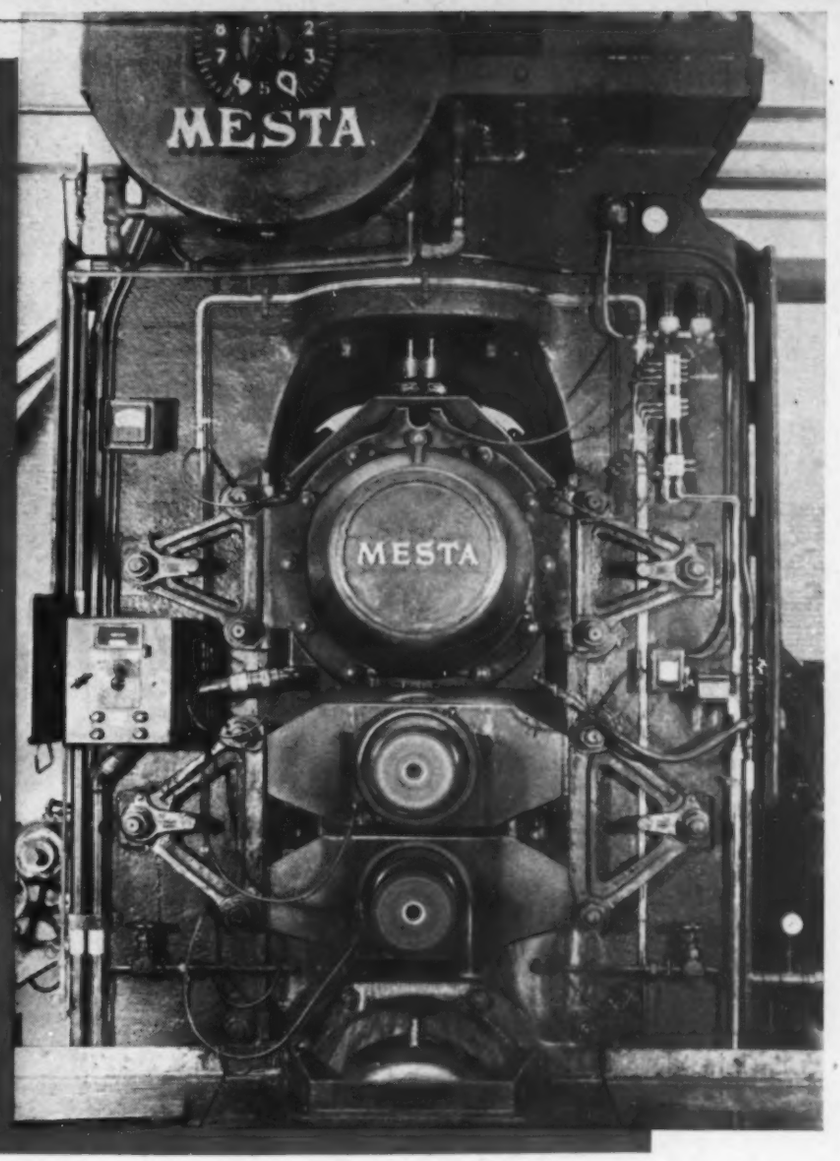
SALEM

ALL OFFICES STAFFED FOR . ENGINEERING, CONSTRUCTION and OPERATION

Salem Builds

CIRCULAR SOAKING PITS
ROTARY HEARTH FURNACES
CONTINUOUS BUTT-WELD FURNACES
CAR BOTTOM FURNACES
FORGE FURNACES
HEAT TREATING FURNACES
NEEDLE METALLIC RECUPERATORS
AIR RECIRCULATING FURNACES
GAS ATMOSPHERE FURNACES
MECHANICAL EQUIPMENT FOR CHARGING AND DISCHARGING MATERIAL FROM FURNACES

GIVE THESE BEARINGS 3-WAY PROTECTION



TO MAINTAIN strip steel production, back-up roll bearings must have the 3-way protection of effective lubrication. Use *Texaco Regal Oils.*

Texaco Regal Oils are heavy-duty circulating oils . . . highly refined, turbine grade . . . that (1) stand up under high speeds and temperatures, (2) carry heavy loads easily, and (3) resist oxidation, emulsification and sludge formation. *Regal Oils* thus keep circulating systems clean . . . prevent costly stoppages . . . assure continuous production without expensive maintenance.

On the drive side, protect your heavy-duty enclosed gears (including worm gears) with *Texaco Meropa Lubricants.* Their load-carrying capacity is higher than any possible shock loads or pressures . . . and they prevent bearing corrosion.

Let Texaco Products and Lubrication Engineering Service help you maintain production. Just call the nearest of the more than 2500 Texaco distributing plants in the 48 States, or write:

The Texas Company, 135 East 42nd Street, New York 17, New York.

TEXACO

TEXACO Regal Oils
(HEAVY DUTY CIRCULATING OILS)

Tune in . . . TEXACO STAR THEATRE presents the NEW TONY MARTIN SHOW every Sunday night. See newspaper for time and station.

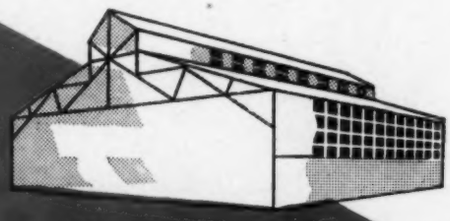
ROLLING TECHNIQUE . . .

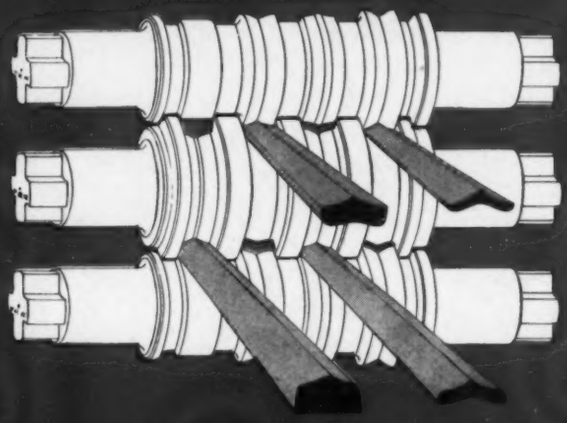
Angles

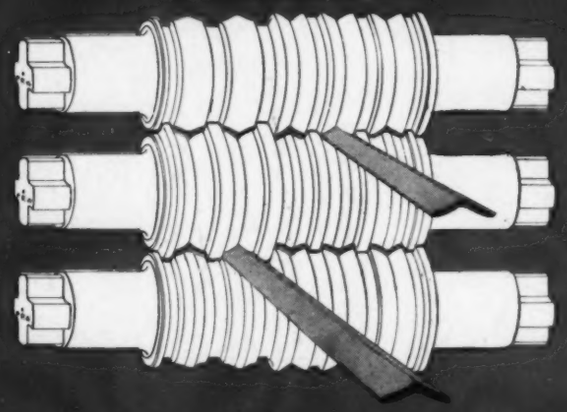
Angles, of both the equal and unequal types, are probably the most commonly rolled shapes. Equal angles from ¾″ x ¾″ to 8″ x 8″ and unequal angles from 1″ x ¾″ to 10″ x 4″, cover a wide range of sizes having hundreds of uses. Numerous sizes of these angles are rolled of non-ferrous material as well as steel.

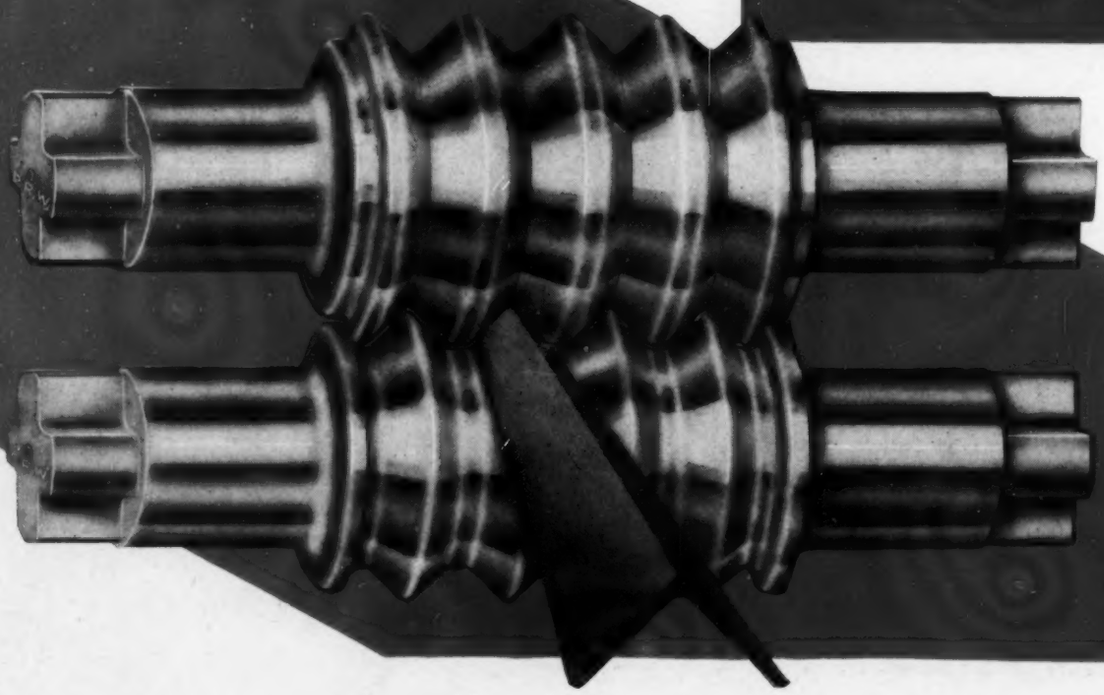
Pittsburgh Rolls with over three-quarters of a century of roll-making experience and satisfactory performance behind them, can be relied upon to deliver production of highest quality for which high speed modern mills are designed, at *less cost per ton of steel rolled.*

PITTSBURGH ROLLS
Division of Blaw-Knox Company
PITTSBURGH, PA.









PITTSBURGH ROLLS

2 STEPS in Cutting Costs of handling bagged material

1 *Install* BAKER *Fork Truck and Pallets*

This will eliminate the back-breaking labor of handling individual bags manually, cut time and cost of car-loading or unloading, add storage space by tiering, and speed inter-department handling.

2 *Get Suppliers to Palletize Shipments*

This will cut time and cost of unloading incoming material. Supplier will make corresponding savings at shipping end with Fork Truck-Pallet combination. Damage in transit minimized.

Baker Fork Truck tiering pallet loads of bagged starch in storage. Note method of "locking" sacks to prevent side-slipping.

AT THE ERIE, PA. PLANT of one of our customers, raw materials such as clay, starch and talc, are received in bags. A typical carload will contain some 1600 bags, weighing about 50 lbs. each. These bags must be unloaded, stored, and transported to process departments as required.

This company took Step No. 1 years ago, and from the receiving point all bagged materials are carried in unit loads on pallets by fork truck. This has resulted in substantial savings each time the material is handled and has increased warehouse capacity by permitting high tiering. But bags not on pallets when they arrive must first be palletized—an operation requiring about 14 hours per car.

Step No. 2 is now under way. Arrangements are being made with all suppliers of bagged materials, to ship in unit loads, on pallets. Such carloads can be completely unloaded and stored in not much over two hours—as against 14 hours for palletizing alone. Since no individual manhandling of bags is required, heavy labor is eliminated, and damage from handling and shipping is minimized. Comparable savings are realized by suppliers at the shipping end, making it possible to improve deliveries.

Savings possible by complete palletization are demonstrated at the same plant in the case of shipping cartons. For these, which arrive in "knock-down" condition, the company furnishes the supplier with special four-way pallets—and the "flats" arrive in unit loads strapped to these pallets. Unloading and warehousing now takes about three hours per car, where formerly, when "flats" were received unpalletized, it took 24 man-hours for the job.

Let a Baker Material Handling Engineer show you how you can save money with fork trucks and pallets.

EITA

Member:
Electric Industrial Truck Association

BAKER INDUSTRIAL TRUCK DIVISION *of The Baker-Raulang Company*
2166 WEST 25th STREET • CLEVELAND, OHIO
In Canada: Railway & Power Engineering Corporation, Ltd.

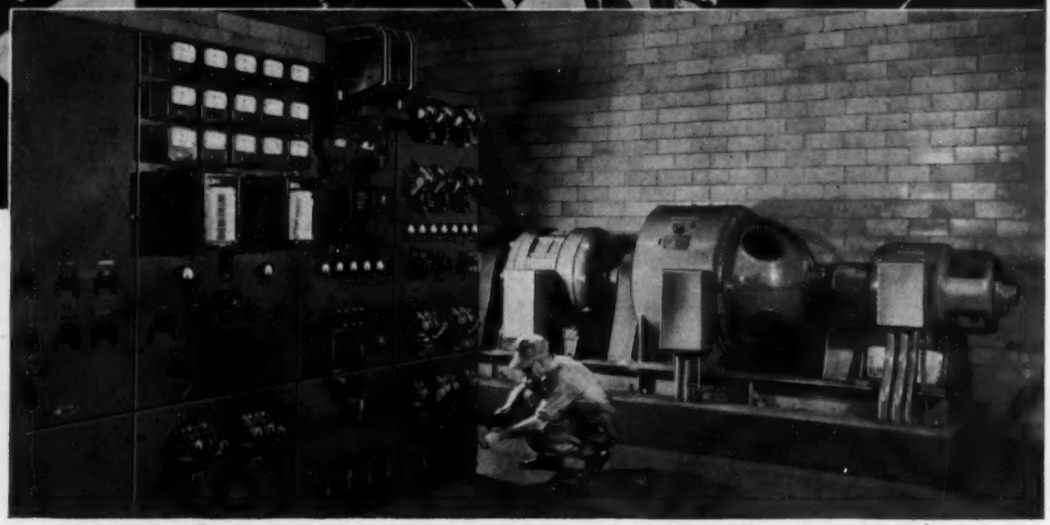
1800-1-47

Baker INDUSTRIAL TRUCKS

CALL ON ALLIS-CHALMERS FOR...

THIS 7,000 HP MOTOR

operating a 44-inch reversing blooming mill is capable of exerting a repeated operating torque of 225 per cent of rating, and can exert 275 per cent of normal torque before circuit is interrupted.



THREE PANEL CONTROL BOARD AND EXCITER SET

for the 7,000 horsepower reversing blooming mill motor. The number of contactors required is reduced to a minimum by the use of the *Regulex* control set described at the right. Fewer contactors greatly simplifies the installation and maintenance of control equipment.

Transformers

Switchgear and Switchboards

Rectifiers

Motors for Mill Drives

ALLIS

1847 1947 A CENTURY OF SERVICE to Industry THAT MADE America Great

One of the Big 3 in Electric Power Equipment—

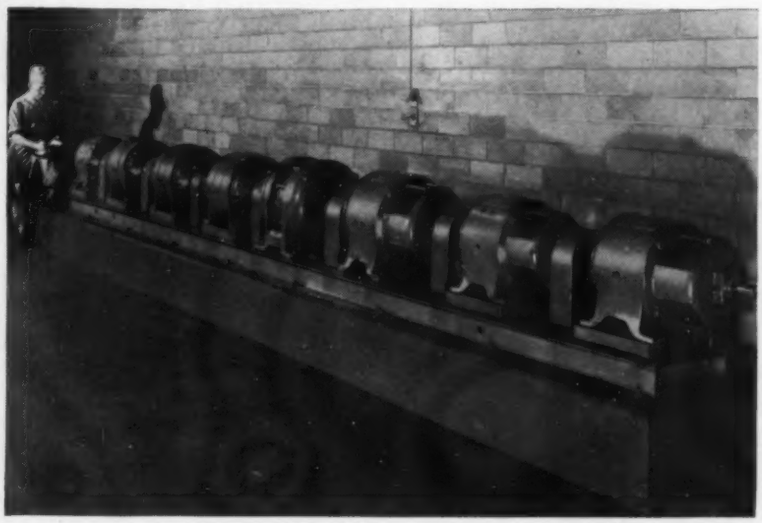
COMPLETE MAIN MILL DRIVES!

Whether you need power for a Blooming, Slabbing, Roughing or Finishing Mill, a Hot Strip Mill or a Cold Reduction Mill, Allis-Chalmers can help you!

OVER FIFTY YEARS' experience in the design and manufacture of electrical machinery has given Allis-Chalmers the ability to fulfill *completely* any main mill power and control requirements.

Here's typical evidence. In a large midwestern steel plant, from the Reversing Blooming Mill to the Finishing Mill, Allis-Chalmers has furnished *all* the main mill drives and control.

When you deal with Allis-Chalmers you enjoy practical benefits of A-C's long years of experience —you benefit by sturdy, generously proportioned design and long lasting construction which is typical of Allis-Chalmers equipment. ALLIS-CHALMERS, MILWAUKEE 1, WIS.



REGULEX EXCITER SET INSTALLATION

Regulex control provides uniformity of acceleration and maximum speed stability, and reverses motors in less than 2 seconds with current automatically limited to a safe operating value.

ALLIS-CHALMERS SYNCHRONOUS M-G SET

used to support a 5,000 horsepower intermediate mill motor. Set consists of two 2,000 kw, 700 volt d-c generators driven by a 6,000 hp, 6600 volt, 514 rpm synchronous motor.

A 2214

CHALMERS

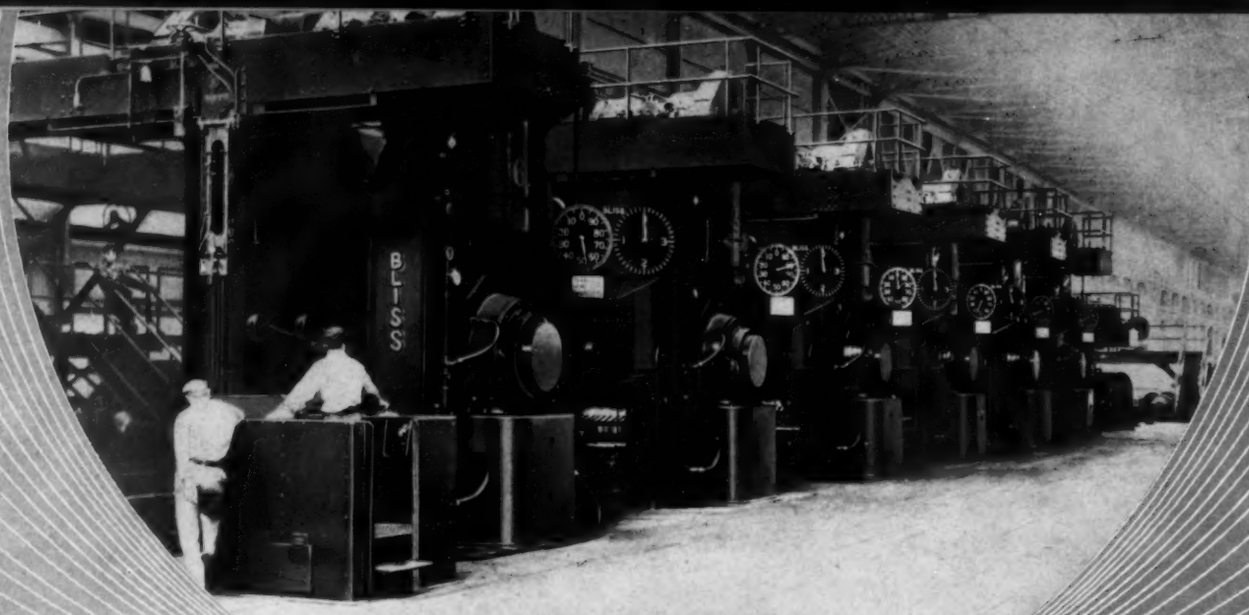
Steam and Hydraulic Turbines

Centrifugal Pumps

Blowers and Compressors

Texrope V-Belt Drive

Biggest of All in Range of Industrial Products



Bliss 21" x 48" x 48" Hot Strip Mill.

Rolling Mill efficiency in full measure

Why do so many outstanding sheet and strip mill installations carry the Bliss name-plate? Because "Bliss-Built" means year-in and year-out operating efficiency...a product of field-seasoned engineering geared to each individual rolling requirement, large or small.

Bliss builds two-, three- and four-high mills for hot and cold rolling, single stand reversing, or tandem operation on ferrous and non-ferrous metals; also cluster mills—plus a wide variety of accessory equipment, including mandrel type hot coilers, upcoilers, slitters, reels, etc.

For a full measure of rolling mill efficiency, call on Bliss. Our engineers will gladly work with you in appraising your current needs.

STAY AHEAD WITH *Bliss*

E. W. BLISS COMPANY
Salem, Ohio

- rolling mills
- mechanical and hydraulic presses
- can and container machinery

Skylift Wins on "Point Test!"

COMPARISON PROVES

Feature for feature Skylift Outpoints All Other Fork Trucks

1 The only hydraulic electric truck with automotive type controls:
Operates like a car—anyone who has driven an automobile, can operate the Skylift!

2 Single operating handle for lift and tilt control:
Simplicity of control. Lever, just below steering wheel similar to gearshift lever on newer model cars. Speeds operation—reduces operator fatigue.

3 Can lift, tilt and drive simultaneously or independently under all load conditions:
Speeds operation. Provides easier and faster spotting of loads since lifting and tilting can be accomplished while Skylift is in motion.

4 Forks elevate full height of first lift without increasing overall height:
Forks and uprights move independently to give you full 67 inch single lift before increasing upright height beyond standard 83 inches. Stack to ceiling height in low clearance buildings and boxcars without uprights extending above load.

5 Automatically controlled pre-set lowering speed:
Eliminates possibility of damage to load caused by excessive lowering speeds. No danger of load dropping violently.

6 130" lift with 83" collapsed height of uprights:
New high in lifts for fork truck with standard 83" overall collapsed height of uprights. Higher storage possible, still truck will pass through standard 7 foot high door.

7 Dual chains are load equalized and fully compensated:
Safety—longer chain life. 2 separate chains are used instead of double width chain. Each chain has sufficient capacity to hold load.

8 Fork carriage equipped with special design thrust rollers:
Prevents upright spreading. Also if off center loads are handled, fork carriage will not twist.

9 Reversible drive wheels:
Off center mounting provides increased overall width dimension when drive wheels are reversed ... greater stability on rough or uneven runways.

10 All wheels demountable without disrupting wheel bearing adjustment:
When wheels are removed for tire replacement, bearing alignment cannot be disturbed.

11 Full magnetic contactor control:
Foolproof operation—Truck is either in speed or out of speed. No burning or arcing in controller. Increases life of electrical equipment.

12 Automatically timed master controller (NEWmatic):
Provides automatically timed sequence of four speeds in forward and reverse directions. Completely eliminates tendency of truck operator to start in higher speed, since NEWmatic controller allows truck to start *only* in first speed and pass through faster speeds *only* in proper sequence. Smooth starting, reversing, or accelerating eliminates tire slippage. Reduces peak electric current surges by two-thirds.

13 Foot accelerator pedal for speed control:
Automotive type control—speeds up operation. Simplicity.

14 Disc type brake:
Smoother, easier, positive stopping. Equalized braking power under all operating conditions. Self-aligning for long life.

15 Automatic tilt stops in backward, vertical and forward positions:
Safety. Uprights always centered at vertical position when moving either backward or forward. Reduces possibility of load spilling.

16 Silicone Varnish for motor insulation:
Virtually eliminates possibility of damage to motors from overheating. Applied over glass, mica, or asbestos, it is thus the most effective insulation known to electrical engineers.

Plus These All-Star Features

Dead-man control • Caster-type steering axle • Center control • Operator's position accessible from both sides • Low center of gravity.

NO OTHER FORK TRUCK HAS THESE 16 EXCLUSIVE FEATURES

Skylift
ELECTRIC TRUCK
A PRODUCT OF AUTOMATIC
Lightens LIFE'S LOADS

ONLY AUTOMATIC MAKES THE FAMOUS SKYLIFT ELECTRIC TRUCKS, TRANSPORTERS AND TRANSTACKERS

Send Coupon for "POINT-TEST" Proof of Material Handling Savings

AUTOMATIC TRANSPORTATION COMPANY
DIV. OF THE YALE & TOWNE MFG. CO.
115 W. 87th St., Dept. 00, Chicago 20, Ill.

☐ Please send me "POINT-TEST" Proof of Skylift material handling superiorities.
☐ Have an ATCO Specialist make a free survey of my material handling costs.
☐ Schedule me for a showing of ATCO's new film, "Pay Loads Pay Off."

Company Name.....
By.....
Street Address.....
City..... State.....

STEEL PRICES

COSTS

COSTS

COSTS

COSTS

COSTS

Maybe you'll find the answer in the BILLET SHED

How are you going to hold the profit line with fixed base prices and increased wages, advancing fuel prices, the possibility of higher freight rates . . . costs advancing generally?

Some mills are finding at least part of the answer in the billet shed.

They find that one man with a Bonnot Billeteer does the work of ten manual chippers . . . does it neater and better . . . releasing men for less killing, more profitable work.

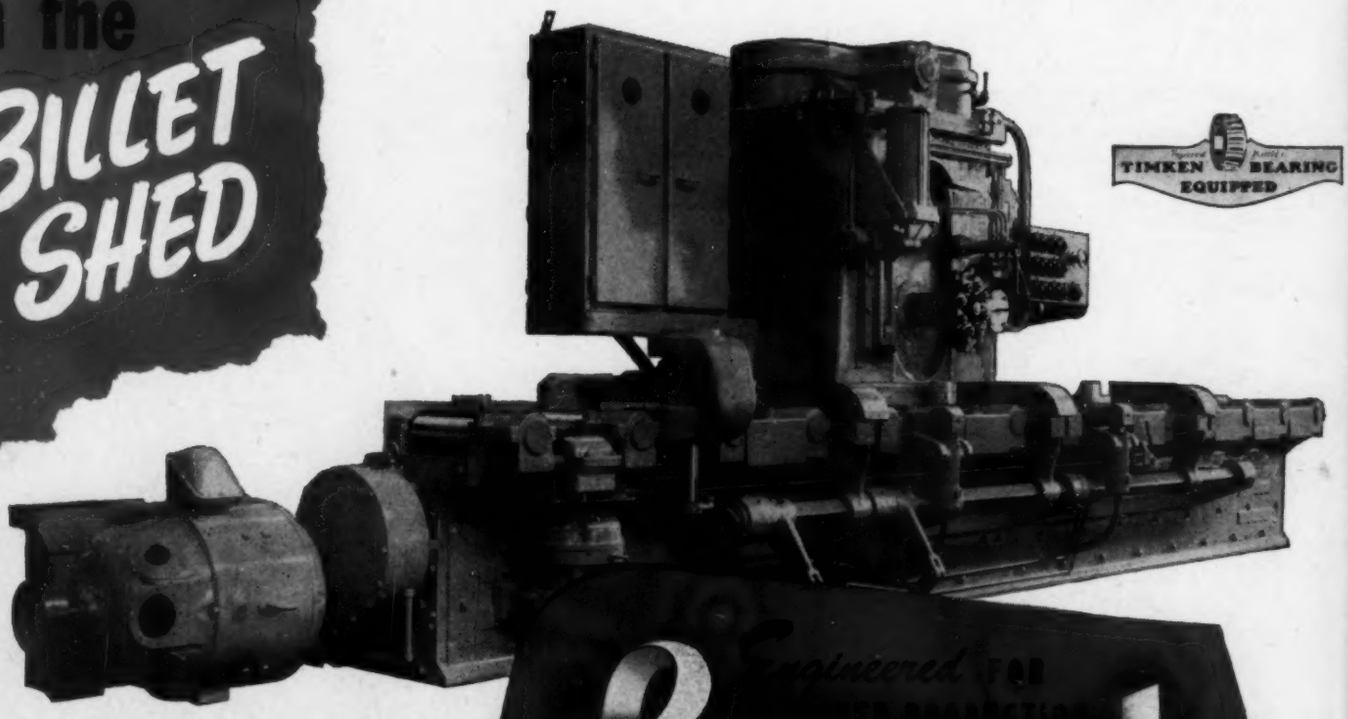
They find the Billeteer never tires . . . never gets groggy or jittery . . . never has "off" days. Production never suffers.

They find the Billeteer saves tons of clean, known-analysis chips ready for remelting.

They find it readily conditions billets which ordinarily would be scrapped because of the prohibitive cost of manual chipping.

They find Bonnot Billeteers, used with the Bonnot Mechanical Inspection Table, completely mechanize the billetshed — and sharply slice conditioning costs.

It will cost you nothing to have the facts. Write.



TIMKEN BEARING EQUIPPED

Engineered for

Bonnot

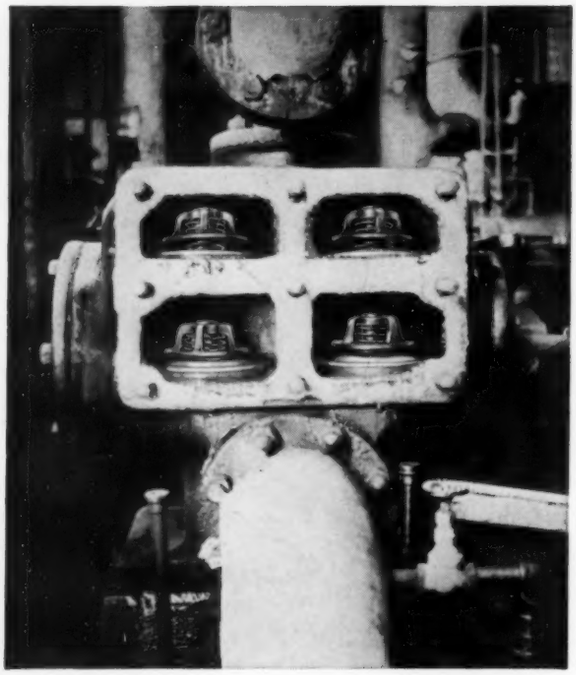
BUILDERS OF THE BILLETEER

CANTON 2, OHIO

For further cost-cutting help, investigate Bonnot Charging Tables, Clay Mixers, Grinding Pans, Clay Feeders, Cold Saws.

A Product of
UNITED ENGINEERING
AND FOUNDRY COMPANY
Pittsburgh, Pennsylvania

KEEP PUMPS IN SERVICE WITH DURABLA VALVES



- **REHABILITATE OLD PUMPS**
- **REFIT THEM FOR NEW SERVICE**
- **DURABLA - EQUIP NEW PUMPS**

The records of the DURABLA Engineering Department show numerous examples of old reciprocating pumps which have been rehabilitated or adapted to new and severe service by fitting them with DURABLA PUMP VALVE UNITS.

At a time when most types of mechanical equipment are difficult to obtain — and when maintenance man-power is not too plentiful — DURABLA Valves can be the answer. They will keep some pump in action or refit it for another service.

The adaptability and long term reliability of all types of reciprocating pumps are primarily dependent on their valves. DURABLA Valve units, widely used for replacements on every type of reciprocating pump may prevent costly delays or make it unnecessary to delay operations while awaiting new equipment.

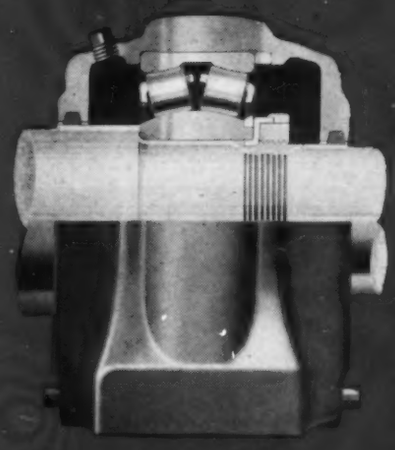
11 Standard Sizes of DURABLA Metal Pump Valve Units to Meet Over 300 Installation Requirements.

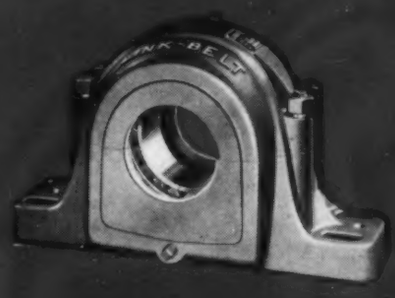
Address DURABLA Engineering Department For Information and Bulletin: Reference 758

*Patent Numbers 2090486, 2117504

DURABLA MANUFACTURING COMPANY
114 LIBERTY ST. NEW YORK
BRANCHES IN PRINCIPAL CITIES. FOR CANADA REFER: CANADIAN DURABLA LIMITED, TORONTO

► To claim long life—to claim efficiency—to claim accuracy for Link-Belt Ball and Roller Bearings is merely to accent the obvious. More interesting to you is the completeness of Link-Belt's Ball and Roller Bearing line—mounted and unmounted. Still more interesting is the nation-wide organization of expert Link-Belt Bearing Engineers, whose sole service to Link-Belt rests *in their service to you*. Use our books (No. 2094 and 2095 sent immediately upon request)... but use also the expert knowledge of our Bearing Engineers on your design problems.





1 Heavy series precision-built double row self-aligning roller bearings.

2 Inner ring directly mounted on precision turned or ground shafting assures greatest accuracy.

3 Locknut clamps assembly securely to shaft and is prevented from loosening by serrated lock washer.

4 Felt seals for grease lubrication or "Spiro-Seals" for oil or grease lubrication.

5 True flat surfaces assured for end pressure surface.

6 Housings drilled and tapped for drain plugs on both sides.

7 Casting spotted for dowel holes to locate unit on support. Slotted holes for foundation bolts.

8 Sturdy, compact, split housing provides convenience in mounting, lubrication and disassembly.

9 Tapped holes in cap take standard screw to raise cap off base without damage to finished surface.

10 Permits different methods of lubrication, such as grease, constant level oil or circulating oil.

11 Bearings can be fixed or floated axially. "C" spacers may be inserted or removed as required.

LINK-BELT COMPANY

Chicago 9 • Indianapolis 6 • Philadelphia 40
Atlanta • Dallas 1 • Minneapolis 5 • San Francisco 24
Los Angeles 33 • Seattle 4 • Toronto 8 • Offices, Factory Branch Stores and Distributors in Principal Cities

LINK-BELT

THE SYMBOL OF QUALITY LB LINK-BELT

BALL AND ROLLER BEARINGS

new "twin-motor" temper mill drive holds high tension accurately at 3700 fpm!

G-E engineered drive paves the way for higher rolling speeds and greater production of quality steel

Here is another fine example of General Electric drive engineering and how it can save time and money for steel operators. It is the recently developed twin-motor drive for a two-stand temper mill. The new drive combines all the advantages of twin motors on each stand with an exceptionally accurate method of controlling tension between stands.

Trial tests showed that the new mill can be operated as fast as 3700 feet per minute and still have strip tension between stands within very close limits. Key to the success of the new drive is a unique combination of amplidyne control and a high-accuracy General Electric regulating tensiometer used to hold strip tension between stands within close limits. The drive on this new mill also maintains tension accurately between the stands and pullers, as well as between the pullers and reels by the use of conventional amplidyne current control.

Specifically, this new General Electric temper-mill drive provides the mill operator with these important advantages:

- *It enables the operator to compensate electrically for unequal roll diameters, thus eliminating the necessity for exactly duplicating work-roll diameters.*
- *It eliminates pinion stands and the expense of maintaining them.*
- *Most important, it reduces inertia, thereby permitting the mill to be accelerated or decelerated more rapidly with accurate control of tension to provide increased production of high-quality steel.*

General Electric amplidyne control performs a number of important functions in this new mill drive. It holds tension accurately throughout acceleration, running, and deceleration. It automatically synchronizes the speed of the winding reel with the strip speed. In addition, amplidyne control has eliminated numerous heavy control contactors, replacing them with small, easy-to-maintain relays.

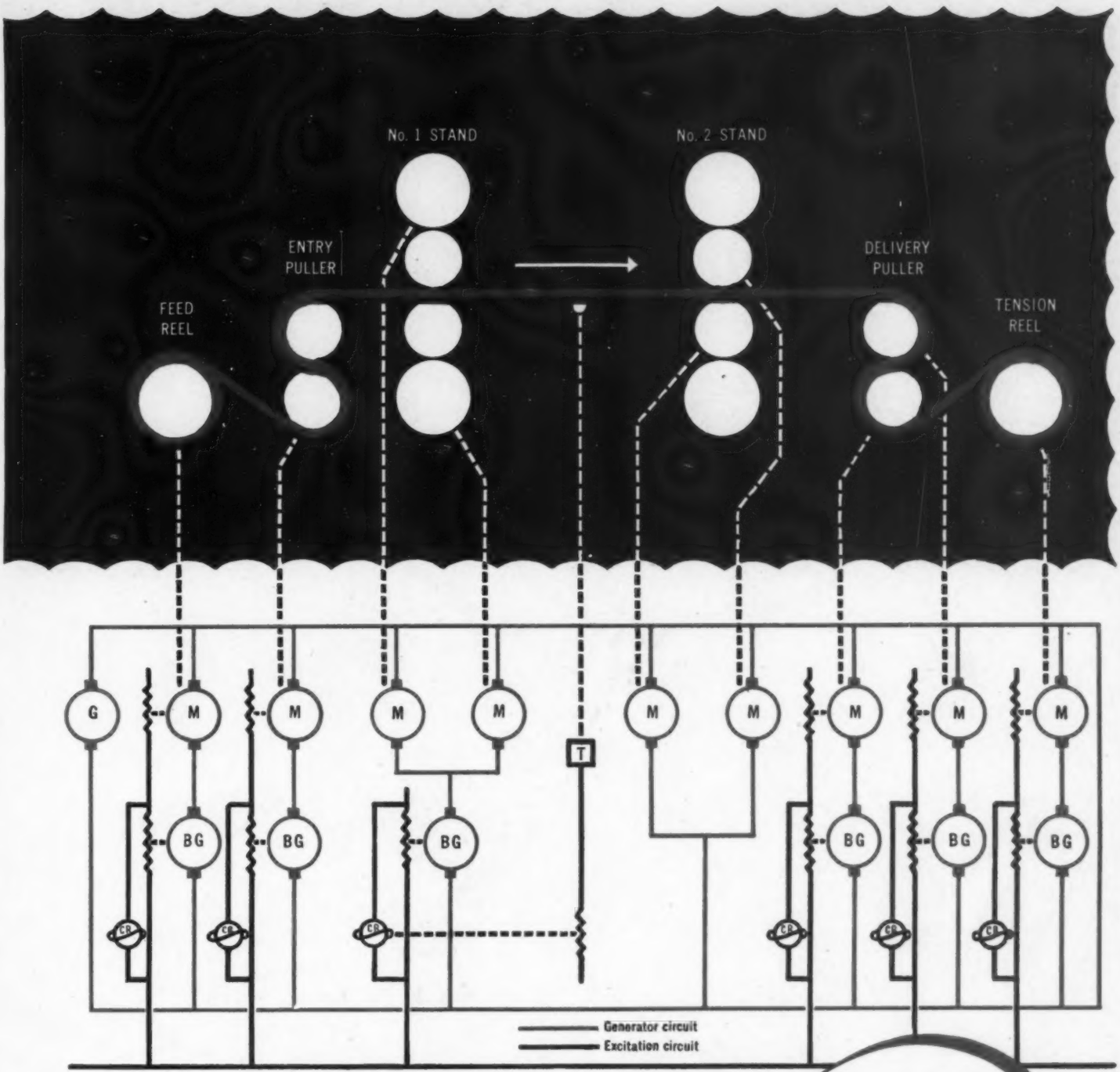
Because this General Electric drive is engineered and installed as a unit, you are spared the trouble and expense of co-ordinating all the components of modern mill drives—motors, controls, cable, and power distribution equipment. In co-operation with your own technical personnel, General Electric makes sure that every equipment selected is the right one for the job. Then, General Electric assumes responsibility for securing delivery of all the electrical components. Until the drive is installed and running smoothly, a G-E steel-mill specialist's help and experience are freely available. Why not consult the steel mill specialist in your local G-E office on your drive problems *now? Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

A QUICK EXPLANATION *of this new mill drive!*

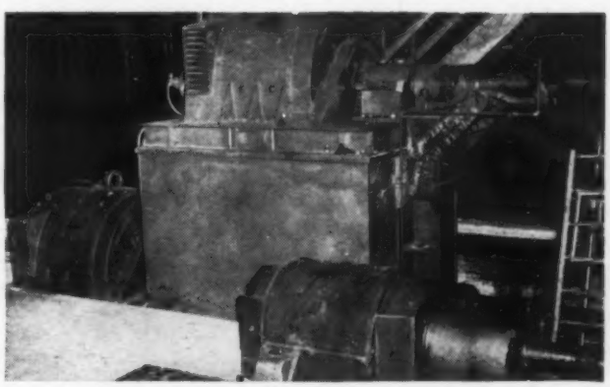
Strip tension between the No. 1 and No. 2 stands of this temper mill is measured by a regulating tensiometer (T). As tension rises or falls below a pre-set value, the strip exerts a varying pressure on the tensiometer roll. This is translated into an electrical signal and transmitted to a General Electric amplidyne (CR). The latter functions as a regulating exciter. It amplifies the control signal and uses it to vary the excitation of the booster generator (BG) in series with d-c motors (M) driving the No. 1 stand of the mill. As tension tends to decrease, the excitation power decreases, the motors on the No. 1 stand slow down and exert an additional drag on the steel strip. As tension tends to increase, the Amplidyne increases the booster generator excitation, thereby increasing motor speed and restoring the tension to its normal value. The main generator is shown as (G). Tension is also maintained between feed reel and the entry puller as well as between the delivery puller and the tension reel. An electrical signal is fed into separate amplidynes which vary the excitation of the drive motors on each reel or roll.

GENERAL ELECTRIC

659-41



Twin motors driving back-up rolls on stand No. 1, and drag generator on entry-puller



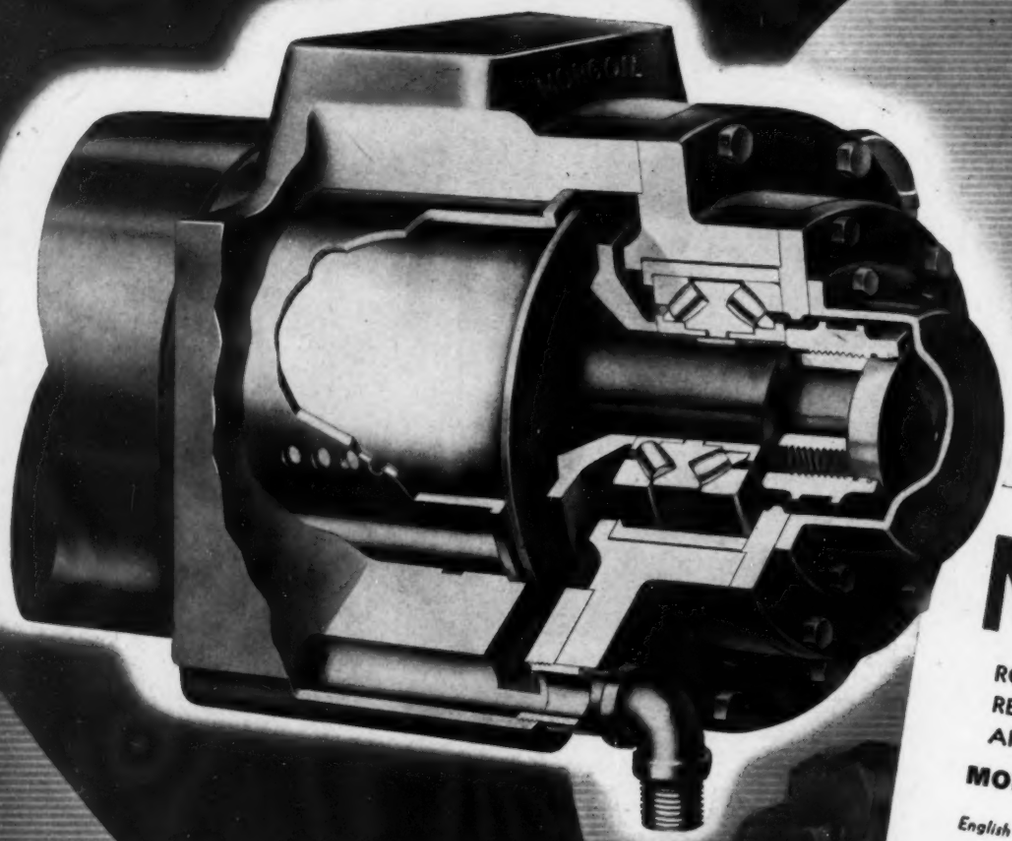
another example of GE drive engineering at work!

MORGOIL BEARINGS

113 customers have bought over 4900

Combined capacity:

4,799,800,000 LBS.



"Be not the first by whom
the new are tried,
Nor yet the last to lay
the old aside."

MORGAN
WORCESTER

ROLLING MILLS • WIRE MILLS
REGENERATIVE FURNACE CONTROL
AIR EJECTORS • GAS PRODUCERS

MORGAN CONSTRUCTION CO.
WORCESTER, MASSACHUSETTS

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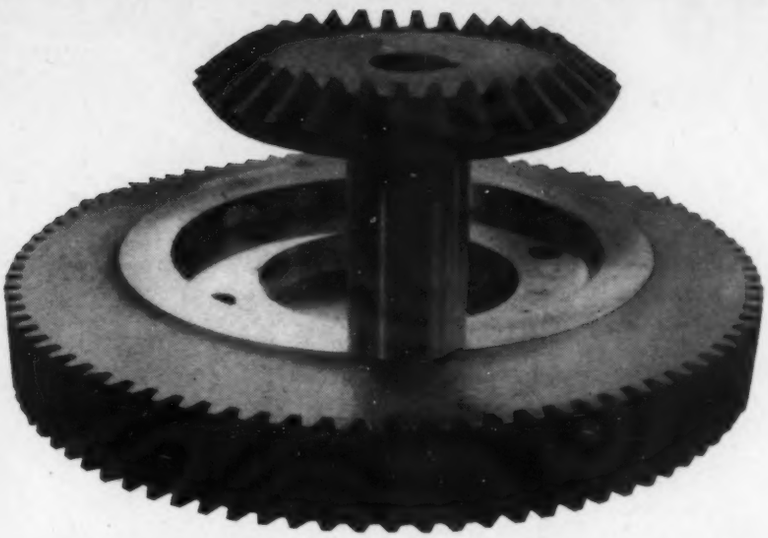


Special gears and (below) mandrels show extreme of heat-treated work handled by Maintenance Department, Sonoco Products Co., Hartsville, S. C. in their Vaporcarb-Hump and Homo Furnace.

NO TWO HEAT-TREATMENTS ALIKE?

Vapocarb-Hump and Homo Methods Meet Varied Needs

Jobbing shops and maintenance departments find Vapocarb-Hump Hardening, with Homo Tempering, especially useful because these Methods are highly efficient for handling a constantly-changing variety of heat-treating work. Flexible, dependable operation is backed up by a number of specific features:

Complete freedom from scaling, pitting and decarburizing is assured by Vapocarb-Hump's atmosphere. This can be merely protective; or can be fully carburizing; can be changed instantly; the amount is always visible. The heat-treater can handle any ferrous alloy at any temperature in the Furnace's range.

Location of the critical by the Hump Method is especially useful as a "window" for looking into the structure of carbon steels, and helps with a variety of heat-treating problems.

Homo forced-convection Tempering gives all benefits of the pioneer in its field. The work space is surrounded by the cylindrical heater, with the convection fan directly below. Heat therefore reaches the work equally from all sides, so that any type of work is heated smoothly and to exact temperature desired.

Micromax D.A.T. (duration-adjusting type) Temperature Control is used with all L&N furnaces and has complete set of control features. It is fully proportioning; has automatic droop correction or reset; has rate-of-approach control; provides overheat protection. Micromax D.A.T. thus meets every control condition just as the heat-treater desires.

Catalogs on request or an engineer will call if you prefer. Leeds & Northrup Co., 4942 Stenton Ave., Phila. 44, Pa.

LEEDS & NORTHRUP

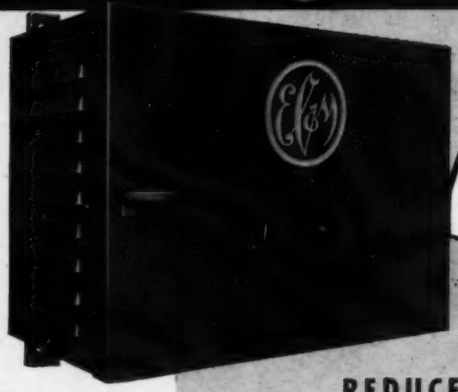
MEASURING INSTRUMENTS · AUTOMATIC CONTROLS · TELEMETERS
HEAT-TREATING FURNACES

Jrl Ad T-620(25)

E&M TYPE WB BRAKE

Solves the A-C BRAKE Problem

....gives better PERFORMANCE too...



Rectifier - Unit in compact form for separate mounting on existing installations.

MANY users of a.c. motor-driven cranes, hoists and machinery are switching to the EC&M Type WB Brake with rectifier-unit. Its *high-speed performance* and *reduced up-keep* for a.c. circuits have prompted its nationwide acceptance. Repeat orders indicate standardization on the WB Brake wherever a.c. brakes are needed.

These brakes not only eliminate the laminated members required in a.c. brake design, but give quick response. High initial current insures *fast release;* automatic reduction of the holding current results in *fast setting.*

The rectifier-unit is compact and is arranged for separate mounting for existing installations. On new projects, it may be combined with the motor control panel. Bulletin 1006 gives complete details on WB Brakes for a.c. operation. Bulletin 1004-D describes them for d.c. service.

THE ELECTRIC CONTROLLER AND MANUFACTURING CO.

2698 East 79th Street — Cleveland 4, Ohio

REDUCED UP-KEEP *and* BETTER OPERATION

because

No laminated magnets or plungers.
No destructive hammer-blow.
No a.c. chatter.
No coil burn-out due to shoe-wear affecting air-gap.
No motors, gears or pumps.
Has fast release and fast set.
Has ability to permit accurate inching.
Has hand release.
Has solid cast-steel magnet and armature.
Has short armature-movement.
Has thick, molded brake blocks 1/4" to 3/4" thick.

On Cranes, Hoists and Machinery ...the EC&M Type WB Brakes *give* HIGH SPEED PERFORMANCE —REDUCED UP-KEEP

WELDING SPEEDS FABRICATION

AIR TOOLS SPEED WELDING

CHIPPING

GRINDING

SCALING

Modern practices for producing good sound welds put equal emphasis on the preparation for welding—the welding—and the finishing of the weld. High-quality welds require careful performance of all three phases.

Ingersoll-Rand Air Tools have contributed to the advances in welding, especially by improving the preparation and finishing operations.

Improve and speed up your welding and satisfy your welders with I-R CHIPPING HAMMERS for peening, beveling, root chipping, cleaning off excess metal . . . GRINDERS for cleaning, smoothing, polishing, wire brushing . . . SCALERS for cleaning, removing excess metal and spatter . . . DRILLS for studding . . . AIR HOISTS for handling heavy weldments.

In most instances our branch offices can fill your order from their stocks—call them on the phone and start using I-R Air Tools today.

COMPRESSORS • AIR TOOLS • ROCK DRILLS
TURBO BLOWERS • CONDENSERS
CENTRIFUGAL PUMPS • OIL AND GAS ENGINES

Ingersoll-Rand

11 BROADWAY, NEW YORK 4, N. Y.

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DOWELL

SUBSIDIARY OF THE DOW CHEMICAL COMPANY

Full blast!

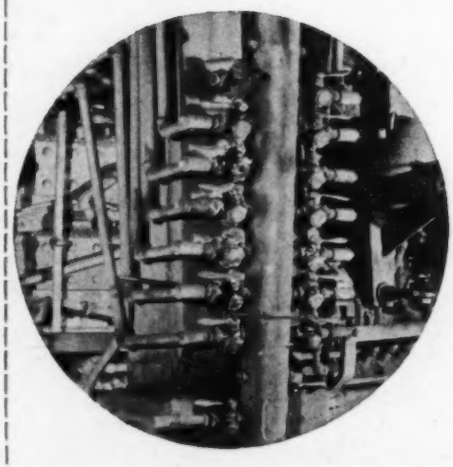
while chemicals clean

the cooling system

The Dowell method of chemically removing scale and sludge from heat exchange equipment has been accepted by many steel plant operators as a rapid, safe and economical way to keep their equipment operating efficiently. In cleaning blast furnace cooling systems by this process, it is not necessary to shut down.

Liquid solvents, carefully selected by Dowell engineers, are pumped into the equipment to be cleaned, filling it to capacity. After a predetermined time, the used solutions are flushed from the unit. Dowell furnishes the necessary trained personnel, truck-mounted tanks, pumps, heaters, mixers and control equipment.

Call the nearest Dowell office for estimates for cleaning: Blast furnaces, open hearth furnaces and other type furnace cooling systems; steam generating equipment—boilers, condensers, economizers, feed water systems; rolling mills cooling systems; engine, compressor and blower jackets; locomotive boilers; water wells, water lines and piping; coke plant equipment—scrubbers, coolers, precipitators, gas lines; building heating, air conditioning, steam and water distribution systems.



DOWELL INCORPORATED, TULSA 3, OKLAHOMA

Subsidiary of The Dow Chemical Company

New York, Boston, Philadelphia, Wilmington, Baltimore, Pittsburgh, Buffalo, Cleveland, Cincinnati, Detroit, Chicago, St. Louis, Kansas City, Wichita, Oklahoma City, Houston, Fort Worth, Shreveport, Mt. Pleasant, Michigan; Salem, Ill.; Borger, Texas; Wichita Falls, Texas; Midland, Texas; Lafayette, La.; Hattiesburg, Miss. Long Beach, Casper: Dowell Associate—International Cementers, Inc.

Dowell service is supervised by trained engineers using carefully selected liquid solvents and special mobile equipment.

DOWELL

FOR INDUSTRIAL CHEMICAL SERVICE

AUTOMATIC FORK TRUCK

DEPENDABLE

POWER

EXIDE-IRONCLAD POWER
AND BATTERY ELECTRIC TRUCKS

Keep materials moving steadily, safely, at minimum cost . . . .

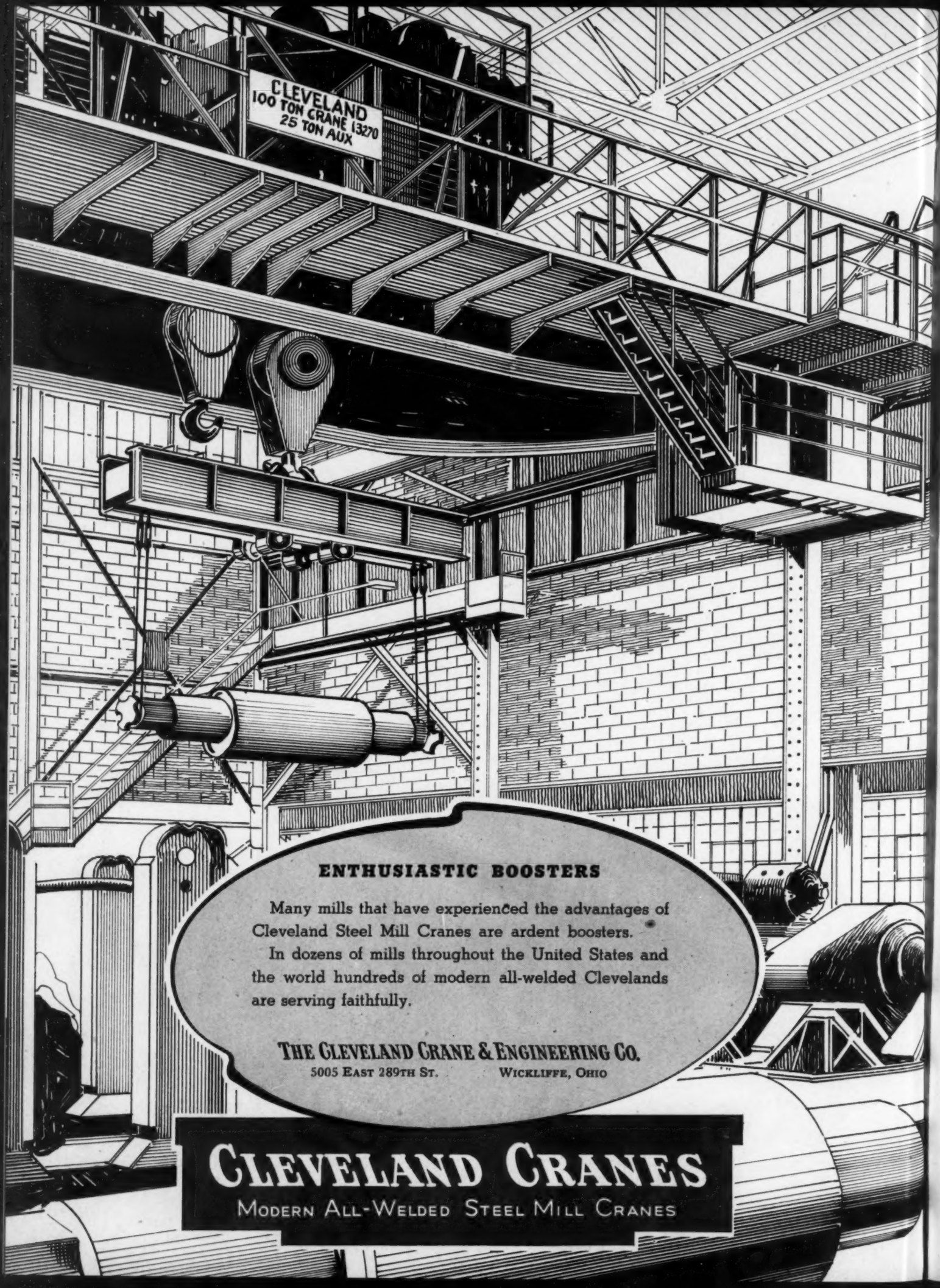
You can make substantial savings in materials handling costs by using the modern, efficient method employed by so many others throughout your industry. They have delegated their loading, unloading, lifting, hauling, placing and stacking to the time-and-cost-cutting team—battery electric trucks and Exide-Ironclad Batteries.

Exide-Ironclad Batteries have the high power ability, the high maintained voltage and the high capacity that materials handling requires. You can always count on Exide-Ironclad Batteries for dependability, long-life and ease of maintenance.

Write us for a FREE copy of Exide-Ironclad Topics which contains "Case Studies" of materials handling problems. It tells how to cut handling costs up to 50% . . . covers latest developments in handling materials from receiving to shipping.

THE ELECTRIC STORAGE BATTERY COMPANY
Philadelphia 32
Exide Batteries of Canada, Limited, Toronto

AUTOMATIC TRANSPORTER



ENTHUSIASTIC BOOSTERS

Many mills that have experienced the advantages of Cleveland Steel Mill Cranes are ardent boosters.

In dozens of mills throughout the United States and the world hundreds of modern all-welded Clevelands are serving faithfully.

THE CLEVELAND CRANE & ENGINEERING CO.
5005 EAST 289TH ST. WICKLIFFE, OHIO

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

Crops *and* Shorts

TESTIFYING before a subcommittee of the Senate Small Business Committee, Walter S. Tower, president of the American Iron and Steel Institute, stated that the present and planned steelmaking capacity is sufficient to meet any apparent demand through 1950. Even now, pressure is easing in tool steel, stainless and alloy steels, and some bar products. The completion of new rolling mill capacity rated at 3,000,000 tons per year will bring the potential capacity for hot and cold rolled sheet and strip to 18,000,000 tons per year, which will help to satisfy demands in these products.

Mr. Tower offered statistics showing that, if all steel-consuming industries operated at their maximum prewar capacity at the same time, their combined demand would be less than the steel industry's present production.

▲

ACCORDING to a quarterly survey by the Department of Commerce and the Securities and Exchange Commission, American industry will spend $3,800,000,000 for new plants and new equipment in the third quarter of 1947.

▲

IN 1800, the per capita cost of running our Federal government was $2.03; fifty years later it was $1.71. In 1900, the per capita cost had become $6.85. Today it is $471.15.

▲

STEEL production during the first six months of 1947 totaled 42,267,320 net tons, a record for peacetime.

▲

IN the first annual address in the Charles M. Schwab Memorial Lectureship of the American Iron and Steel Institute, E. G. Grace said: "I had come up through the operating end and always believed that any troubles we had were due to our sales people — and some think they still are."

Most operating men would want to include metallurgists, too.

▲

TEMPER is one thing you can't dispose of by losing.

A FORECAST by the magazine Fortune shows that producers of capital goods are optimistic about business conditions in the immediate future. The poll upon which the forecast was based shows that 8 per cent of the manufacturers of capital goods expect a sizable increase in business, 17 per cent expect a moderate increase, 33 per cent look for no appreciable change, 33 per cent expect a moderate decrease and only 9 per cent, a sizable decrease.

Incidentally, 80 per cent of the opinions look for prices to remain the same or go higher.

▲

LARGE electric motor and generator business is said to be running now at a rate five times that of 1936.

▲

IN the steel industry, the monthly "quit rate" during 1946 was 3.6 workers per 100, a labor turnover 16 per cent lower than the average in all industries.

▲

ACTIVITY in new mills and plants in foreign countries is hitting a new high as far as United States builders are concerned. Belgium, France, Sweden, Australia, South Africa and India are among those with representatives now in the country to further such plans.

▲

SMALL motors, called electrotors, are being made in England in sizes down to 3/16 in. diameter by 3/16 in. wide. These "flea-power" units will run at 7000 rpm on 1½ volts.

▲

A NEW process for aging whiskey is said to produce three years of age in 72 hours. This is going to make it tougher for the boys who try to drink it up faster than it is made.

▲

IN some quarters there has been much criticism of the increase in steel prices, which ranged from $5 to $10 a ton and averaged less than $6 a ton, an increase of about 9 per cent. This criticism is well answered in a statement from Inland Steel Company, which shows that production costs, since December 1946, have increased more than $10 per ton, due to the following items:

Steel scrap jumped from $26-28 per ton to $40-42, an increase of over 50 per cent.

Wages have been increased more than 20 cents per hour, up 15 per cent.

Cost of coal has gone up more than 20 per cent.

Iron ore cost is over 10 per cent higher.

Fuel oil prices are up 25 per cent.

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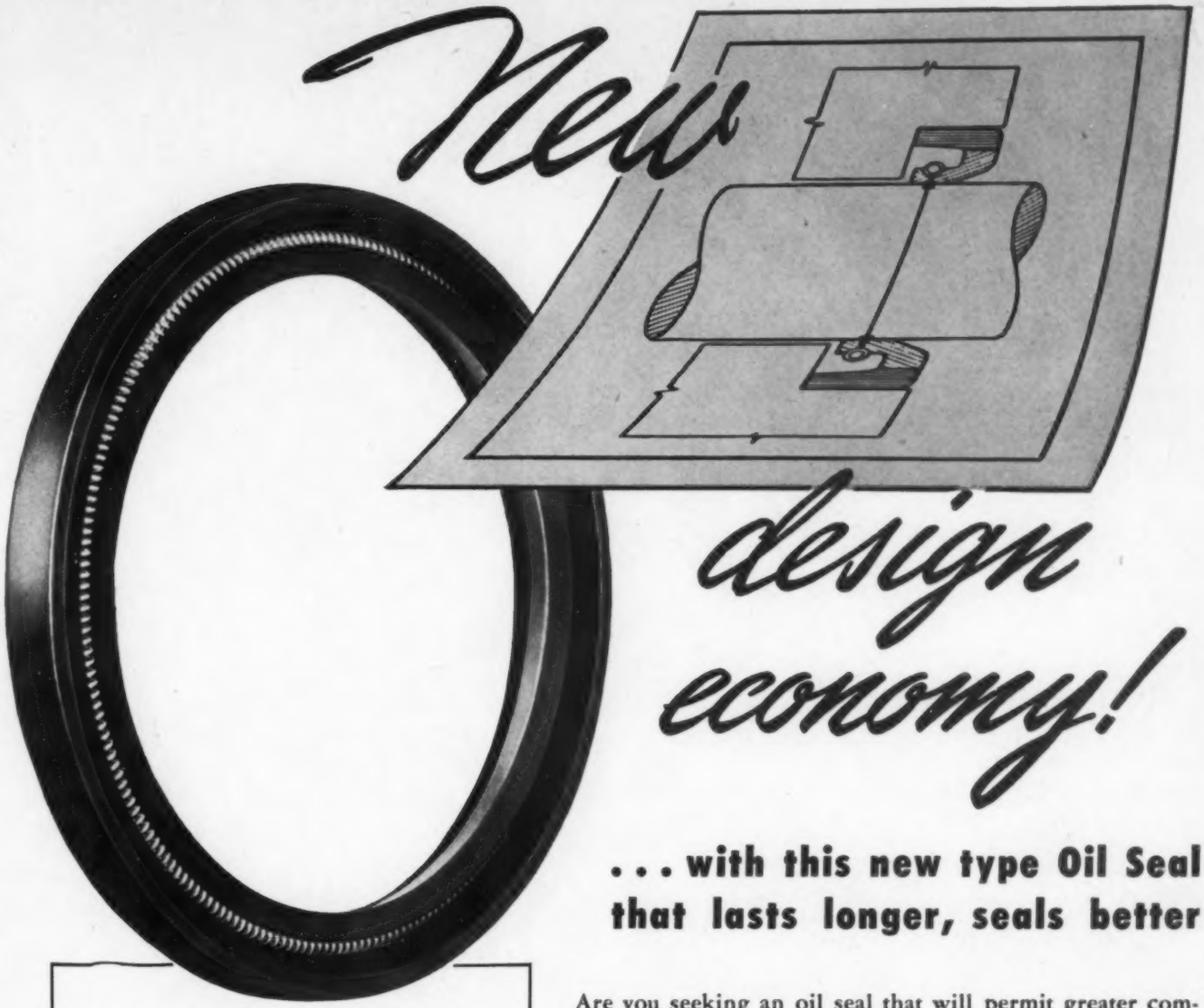

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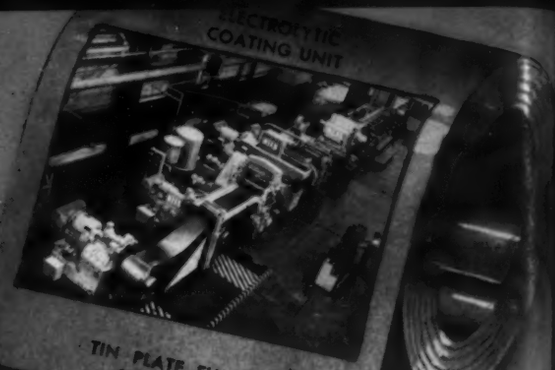

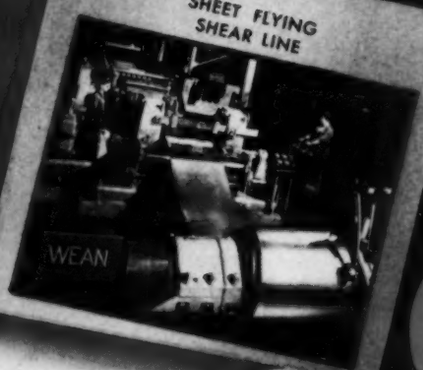

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Power, Fuel and Steam Balances FOR A MODERN STEEL PLANT

. . . . most steel plant power systems have grown like "Topsy," and design of additions must usually be compromised with existing plant conditions . . . . it is seldom that a completely balanced system can be worked out as is done in the case of this hypothetical plant . . . .

RELATION OF THE STEEL PLANT TO ITS ELECTRICAL POWER LOAD

By A. D. HOWRY

Assistant Superintendent, Maintenance - Electrical

Alan Wood Steel Company

Conshohocken, Pennsylvania

▲ MODERN industry has grown to its present status through the close coordination of the basic power that has supplied it. This trend has been more evident in the steel and iron industry than any other development, due to the large amount of energy needed in the process.

The original iron worker beat out his product by hammer, while watching with interest his neighbor using simple rolls driven by water wheels, or horse driven racks, to roll the softer metals such as lead, silver, etc.

Upon the advent of the steam engine the worker applied these principles to his product. These were heartbreaking years, all progress being by the cut and try method; stress analysis, torque, inertia, and other factors were to be investigated and formulas developed later for his use.

This paper is not an historical review, but we must appreciate that progress in steelmaking, equipment design, and power, has been one and the same thing in the development of the present high efficiency of the modern steel plant.

The steam driven rope drive gave way to direct or geared drive, and in turn gave way to the direct current electric drive, which again has now given way to the modern variable voltage individual a-c drives.

This evolution has been governed by the increasing technical knowledge of the design, operating and production engineers.

Summating this knowledge and accomplishment of others, we are about to build a composite or hypothetical modern steel plant, using the latest engineering developments, incorporating maximum efficiency and production, with a minimum of delays and maintenance costs.

Being a complete new plant, we have no problem of revamping or absorbing old and inefficient equipment or contending with dual frequencies in our power distribution and generation.

This plant is a completely integrated unit, with the physical units arranged so as to provide a minimum of movements in the flow diagram of steel production. It is complete from ore handling to the various finished products, including all the units used to meet steel demands.

Consumer demands dictate that we install:

1. Merchant mill.
2. Structural mill.
3. Rod and bar mill.
4. Cold strip mill.
5. Hot strip mill.
6. Rail mill.
7. Plate mill.

Basic supplies for these mills, and to meet the market demand for unfinished and semi-finished products, demand that we install:

1. Blooming and slab mill.
2. Billet mill.
3. Open hearths.
4. Electric furnaces.
5. Blast furnaces.
6. Pig machines.
7. Coke plant.
8. By-product plant.
9. Coke and coal handling.
10. Ore handling and storage.

Coordination of these various units into a group that will constitute a complete plant, providing a minimum of handling with a maximum conservation of heat, will be dependent upon the development of an adequate flow diagram of materials, material handling, shipping, and the heat balance of the plant. This flow diagram must be applied to the topography of the site selected, and the site to be the most desirable should have adequate rail and water shipping facilities and an abundance of clear water for process purposes. The resultant diagram will be the physical layout of the plant.

This hypothetical plant that we have created must be provided with the electric power necessary to drive the units. As the distribution of electric power can be extremely flexible, we have considered the flow diagram

Presented before AISE Philadelphia District Section Meeting, January 4, 1947

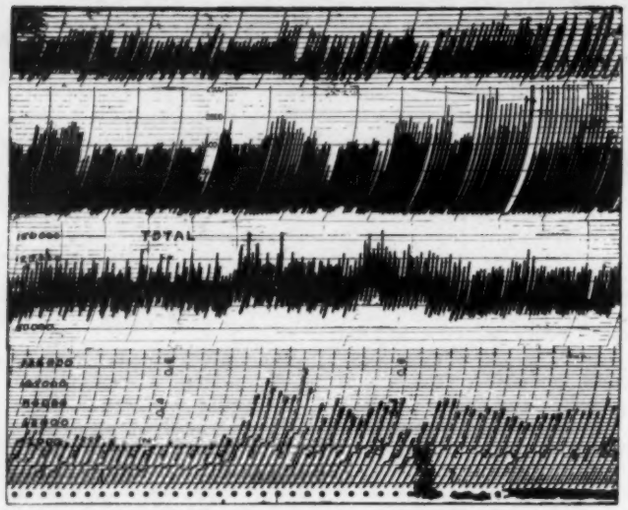


Figure 1 — Bottom curve shows 30 minutes demand, curve above, kilowatt load, and two top curves show two departmental load swings.

of maximum importance and will coordinate the power flow accordingly. This power must, of necessity, meet all demands of the various units and afford the maximum flexibility of operation and continuity of service.

The loads of the various units are fixed by production demands and equipment design, the development of which does not enter the tenor of this study. We appreciate that these loads are extremely variable and must contend with the maximum peaks in the design of our power supply and with the unit departmental demands in the design of our distribution system.

Figure 1 has been prepared showing the thirty minute demand, the integrated kilowatt load and two departmental load swings.

These charts are typical of the average steel plant loads and indicate the necessity of power company interconnection to absorb the peaks rather than extremely high capital investment in generation equipment operating on purchased fuel.

Other chart records show that:

1. No. 1 rod mill with 4000 hp drive has an average of 1600 kw load.
2. The 40 in. blooming mill motor-generator set rated at 5000 hp, swings from 360 kw to 4800 kw.
3. The 40 in. universal slabber with a 6000 hp drive has swings from 200 kw to 5000 kw.
4. No. 2 rod mill with 9400 hp drive, has an average of 5600 kw load.
5. The 56 in. hot strip mill total load exceeds 30,000 kw, with swings from 7000 to 40,000 kw.

In the analysis of loads, we find that the coke plant, the by-products plant, the blast furnace department, and like departments, have fairly constant loads, while the reduction and fabrication mills have extremely variable loads, electric furnace operation creates a swinging load with sharp peaks.

Figure 2 shows the electric load duration curve.

A summation of all peaks shows a rather imposing demand, but a study of the various unit peaks indicates that the integrated maximum peak is in the nature of 160,000 kw, with a thirty minute demand of 126,000 kw, the base load being 43,000 kw, and the energy consumption approximately 75,000,000 kwhr per month.

Frequency control is to be held to approximately 2 per cent plus or minus, over a twenty-four hour period, to provide accurate control for our intricate timing equipment.

The power factor should be in the nature of 0.95 per cent to provide maximum conservation of copper in our distribution systems and minimize line losses.

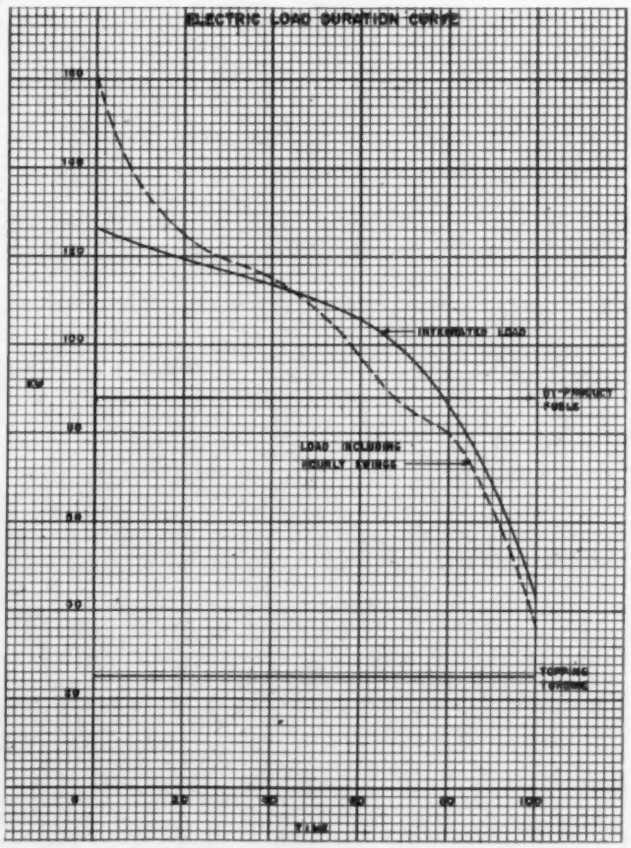
In designing our distribution system, we are governed by our thirty minute demand, realizing meanwhile that consideration must be given to capacity to meet maximum instantaneous peaks with minimum voltage fluxuations.

The electric power system therefore is built to meet the individual power loads and requirements at the various locations, being tied together with the generation and power source by a transmission system that provides flexibility and continuity of service, at the same time isolating extreme fault currents to within reasonable values.

The power source and generation location are fixed by the heat flow chart of the plant, the availability of supplementary fuel, and the public service interconnections. The heat flow is the predominant factor, as supplementary fuel supply, and power interconnections are more or less flexible and can be adapted more readily and with less loss than extensive gas or steam lines.

Considering these factors, the power generation, and power utility interconnections therefore will be centralized at one location in the immediate vicinity of the blast furnaces. This centralization will provide for

Figure 2 — Curves show duration of electric load for the hypothetical steel plant.



maximum efficiency in production, supervision, and flexibility of operation.

Some question may be raised about the advisability of this centralization due to danger of sabotage during war periods or other factors that may indicate decentralization advantages. In this study, we are governed by maximum efficiency and maximum utilization of all waste products and therefore must consider the unit source.

The generation plant design, in addition to meeting all electrical requirements, must utilize to the fullest extent all by-product fuels and be an integral part of the plant flow diagram.

This subject is a study in itself, and is treated in the companion paper.

The number of generating units will be contingent upon this heat balance of the station, but should meet the requirements of flexibility of transmission and distribution.

A review of the heat balance charts shows that of the 126,000 kw thirty minute demand, approximately 88,000 kva can be generated by by-product fuels, 25 per cent of which can be supplied by topping turbines to provide low pressure steam for process and heating purposes. Capacity must be available to meet the maximum peak of 160,000 kw and provide standby in case of failure of any units.

As the plant load is variable from 43,000 kw base to 160,000 kw, a public service interchange is highly desirable, both to provide the excess capacity needed above by-product generation, and to absorb the excess power generated during low consumption periods. It will also provide stand-by capacity during period of unit inspection or maintenance.

The process steam extraction fixes the topping turbines at two, 12,500 kva units, with the condensing turbine installation sufficient to absorb with the topping turbines, the by-product potential generation of 88,000 kw capacity. Installation above this amount is dependent entirely on the flexibility of the public service contract.

This would indicate a minimum of two topping turbo-generators, two condensing turbo-generators, and two public service tie lines, as well as a pair of small house turbines to provide station service, and for boiler auxiliaries.

As the power distribution through our plant is at 33,000 volts, we will purchase power from the public service at this potential and do all our switching on the 33,000 volt bus, which will be an outdoor installation consisting of dual busses, with tie breakers. A synchronizing bus to operating busses will be by interlocked air-break switches.

Each generator will be provided with an independent transformer bank connected directly to the generator terminals to step the output voltage up to 33,000 volts, with the generator breaker being on the 33,000 volt side. As the reactance of these transformers is high, it is apparent that maximum protection is afforded the generators against any system surges; differential protection around generator, transformer and breaker, and instantaneous overload relaying being practically all the additional protection needed.

As all synchronizing is through the synchronizing bus and breakers, the generator breaker will be closed on the dead bus and brought up together with the generator. Synchronization will then be between this bus and the main bus section selected. After paralleling, the associated interlocked air break switch is closed, the synchronizing bus isolated and we are ready to put on another turbine.

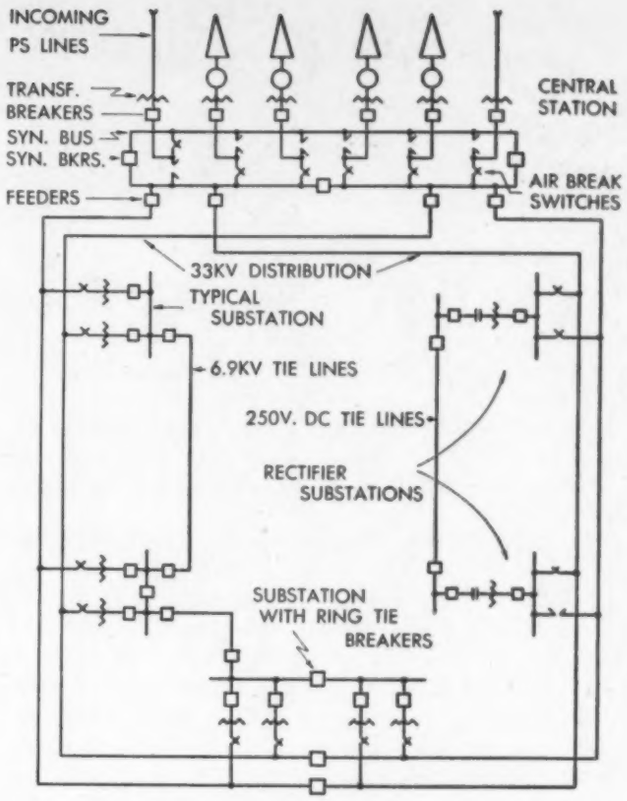


Figure 3 — Power system for hypothetical steel plant.

Each bus section has two 33,000 volt feeders, one east, and one west. These feeders follow roughly the peripheral of the plant, converging in the substation feeding the continuous strip mills at approximately the electrical center of the loop, being tied together with loop circuit breakers controlled from the main power house. These breakers are provided with overload protection and step relaying to prevent closing, unless both feeders are closed and in step, or one section is dead.

The resultant power system is shown diagrammatically in Figure 3. It consists of a dual 33,000 volt loop or ring system around the entire plant, having an rms interrupting capacity of 1,500,000 kva. Sectionalizing is accomplished by remote controlled air-break switches or disconnects, all power and fault interruptions being by oil circuit breakers or high-capacity air-blast breakers.

Distribution and utilization from this system is through high impedence transformers to 6900 volts with the loads so segregated to limit fault currents to a maximum of 500,000 kva.

To provide flexibility, and contingencies such as transformer failure, etc., these secondary systems are interconnected by 6900 volt ties.

The 250 volt direct current system to provide power for cranes, tables, etc., will be supplied by 0.80 per cent power factor synchronous motor-generator sets located

in the various attended motor rooms or substations with outlying load centers being supplied by unattended remote controlled mercury arc rectifiers, the entire d-c system being interconnected by tie lines to provide against interruptions due to failure of any one piece of equipment.

The various power centers, or substations, feeding the coke plant, blast furnace, rolling mills, etc., consist of two or more transformer banks feeding onto a 6900 volt bus with tie breakers.

These transformer banks have motor operated air-break disconnects for high side isolation, with high speed air-breakers of 500,000 kva interrupting capacity to interrupt the load on the 6900 volt side. Interlocking is provided so that the high side air-break disconnects are closed first, then the low side breaker, with the procedure reversed in taking the transformers off the line.

The isolated remotely controlled rectifier substations are provided with motor operated air-break switches for line selection. These are also interlocked to prevent interruption of load currents and paralleling of lines. Switching from one line to the other will mean a momentary interruption, but as the 250 volt d-c system is operating in parallel with other units, no service will be lost. A slight drop in d-c voltage will be the only evidence of the switching procedure.

This constitutes the basic outline of our power generation and distribution system of our steel plant. Any attempt to delve further into the intricacies of the relay protection and capacities of the system would involve considerable time and be beyond the purpose of this study.

Our system is controlled and operated by a power director and his operators by means of supervisory control and telemetering. He has complete control of the system, and works in close coordination with the public service dispatcher in the use and interchange of power between the two systems.

Maximum plant production is contingent upon adequate power supply and distribution flexibility; conversely, power supply is largely contingent upon plant production by-product fuels, the resultant being an integration of processes not present in any other industry. The more thoroughly the integration is affected, the greater the economy in steel production.

This study, together with the companion paper presented, has been prepared basically to show the relation of the steam and fuel balances with the electric power load in steel plant operation.

The creation of the plant is incidental to this study; we realize, of course, that in the basic design of a steel plant, the first requirements are production capacities based on market potentialities.

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RELATION OF THE POWER LOAD TO THE STEAM AND FUEL BALANCES

By HOWARD L. HALSTEAD

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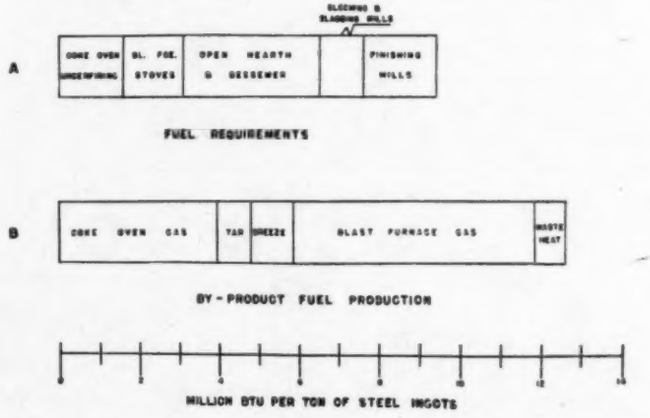
▲ AN INTEGRATED steel plant of the size just outlined in Mr. Howry's paper has several advantages for generating steam and electricity at low cost. It has an electrical load large enough to justify the installation of a power station which will approach the efficiency of modern central stations; it has at its disposal large quantities of waste heat, coke breeze, and blast furnace gas which can be used for generating steam and power; and it demands large quantities of steam which, when supplied from the exhaust of non-condensing turbines will generate electric power at low cost.

PLANT FUEL BALANCE AND STEAM LOADS

The electrical requirements of the hypothetical steel plant being discussed have already been developed in Mr. Howry's paper. In this paper, illustrative figures pertaining to the fuel balance, steam loads, and electrical generating capacity of such a plant will be presented. Although these figures are correct as applied to the hypothetical steel plant under discussion, it is emphasized that they are illustrative only; variations among steel plants preclude the possibility that any such figures be considered as equally typical of steel plants in general.

The fuel requirements of a modern steel plant, ex-

Figure 1 — The fuel requirements shown exclude that required for steam and power, as well as coke for the blast furnace.



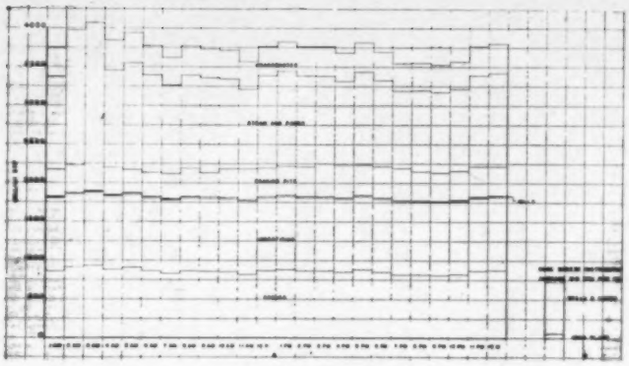


Figure 2 — Blast furnace gas distribution on a typical weekday is shown by this graph.

clusive of blast furnace coke and fuel required for generating steam and power, are shown in the block graph of Figure 1-A. The amount of by-product fuel and waste heat available to the plant is shown in Figure 1-B. These graphs represent Btu per ton of open hearth and bessemer ingots. They were caluclated for a steel plant operating with a blast furnace coke ratio of 0.80 and a ratio of pig iron to steel ingot production of 0.65. The fuel requirements shown represent the efficient utilization of all fuels in every department of the plant.

In addition to waste heat, the only by-product fuels considered as available for generating steam and power are blast furnace gas and coke breeze. Coke oven gas and tar would be used for other purposes within the plant or sold for use outside of the plant.

Figure 2-A represents the hourly distribution of blast furnace gas for a typical day. The amounts of gas shown were calculated for a plant producing 410,000 tons of steel ingots per month. As shown, the major portion of the gas would be used for firing coke oven batteries, blast furnace hot stoves, and soaking pits. Gas which would be lost or unaccounted for is estimated at 10 per cent of total production. Since the gas available for generating steam and power would be bled if not burned in boilers, its cost to the boilers has been set at zero.

Figure 2-B represents coke breeze available to the plant expressed in average Btu per hour. The breeze available each month for steam and power generation is estimated at 18,500 tons. Since coke breeze has a limited sales value, its cost, when burned in boilers, is questionable. In this paper, however, the cost set for coke breeze is also zero.

Figure 3 represents the steam required by the steel plant, exclusive of that required for generating electricity. Figure 3-B represents the amount of such steam which would be generated in open hearth waste heat boilers and that which would have to be generated in fuel-fired boilers. The figures represent pounds of steam per ton of steel ingots. As shown in Figure 3-A, the largest demand for steam is that imposed by the blast furnaces. This demand is based on blowing all blast furnaces with steam driven turbo-blowers.

Figure 3 — Steam required for the steel plant, exclusive of electric power.

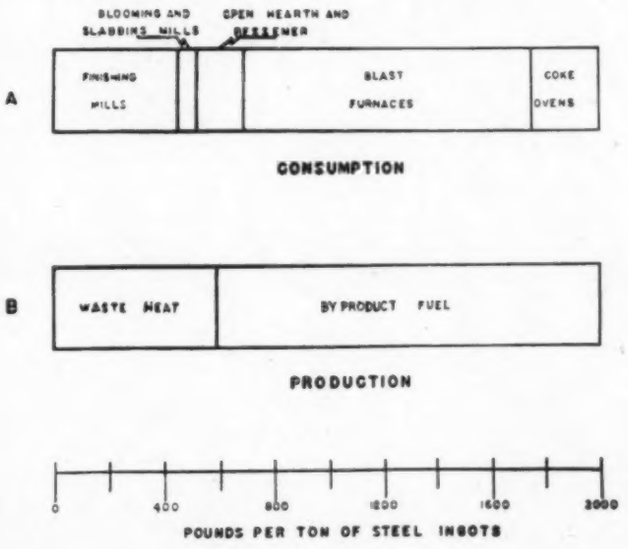
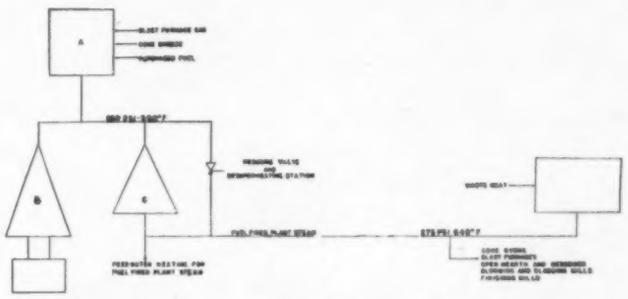


Figure 4 — The basic scheme for generating steam and power is based on an approximate performance of "A," fuel fired boilers with an efficiency of 80 per cent, "B," condensing turbine-generators at 12,500 Btu per kwhr, and "C," non-condensing turbine-generators at 4400 Btu per kwhr, with a throttle flow of 31.5 lb per kwhr, and net steam to plant of 24.5 lb per kwhr.



BASIC SCHEME FOR GENERATING STEAM AND POWER

Shown in Figure 4 is a basic scheme for generating the steam and electric power required by a modern steel plant. The figure is self-explanatory and the approximate thermal performances are indicated beneath the sketch.

The choice of 850 psi steam pressure and 900 F temperature for the fuel-fired boilers burning blast furnace gas, coke breeze, and purchased fuel, is based upon the following considerations:

1. The opinion that these conditions of temperature and pressure are the maximum permissible for reliable operation of steel mill boilers.
2. The increased thermal efficiency that these conditions effect as compared to lower pressures and temperatures for generating electric power. This is particularly true for the non-condensing turbine supplying steam to the 275 psi header.
3. The desirability of operating all fuel-fired boilers at the same pressure and temperature.

TABLE I

Comparative Costs for Three Sizes of Non-Condensing Turbines

	Case I	Case II	Case III
1. Nominal turbine rating, kw	10,000	12,500	15,000
2. Number of turbines installed	2	2	2
3. Total capability = 1.10 x line 1 x line 2, kw	22,000	27,500	33,000
4. Firm capacity, kw	20,000	20,000	20,000
5. Investment cost	$2,560,000	$2,745,000	$2,925,000
6. Annual generation, kw	131,932,000	219,336,000	226,980,000
7. Net annual investment cost = 0.12 (line 5 — 20,000 kw x $120/kw)	$19,000	$41,000	$63,000
8. Fuel savings = line 6 x 0.0081 MM Btu x $.25/$M_m$ Btu	$388,662	$444,155	$459,634
9. Net annual savings, line 8 — line 7	$369,662	$403,155	$396,634
10. Net return, per cent = line 9 ÷ line 5	14.4	14.7	13.6
11. Savings due to increasing installed capacity	.....	$33,493	Increased cost over Case II
12. Increased investment for increasing capacity	.....	$185,000	.....
13. Net return on increased capacity = line 11 ÷ line 12	.....	17.8	.....

The choice of 275 psi pressure for the plant steam mains is based on these considerations:

1. The large pressure drop required to distribute steam throughout the steel plant in pipe lines of moderate size.
2. The opinion that 260 psi steam pressure strikes a satisfactory balance between reliable and economical operation for the turbine driven blowers required for the blast furnaces and bessemer converters. From the performance curves available, the increase in efficiency of such turbines with higher steam pressures and temperatures is not as great as the increase in efficiency of the larger turbines used for generating electric power.
3. The heat drop through a non-condensing turbine bleeding steam from 850 to 275 psi pressure. This drop is large enough to make the installation of such a turbine economically attractive.

SELECTION OF NON-CONDENSING TURBINES

The amount of non-condensing turbine capacity to be installed is related to the fuel-fired steam which is required by the plant. These requirements for a steel plant using steam at the unit rates shown in Figure 3-A and producing 410,000 tons of ingots per month are plotted in Figure 5. They are shown by hours for five typical weekdays, an average Saturday, and an average Sunday. These seven days, or composite week, represent the steam requirements for the plant throughout a year. This steam when bled from 850 psi, 900 F through a non-condensing turbine exhausting at 275 psi will generate electric power at the rates shown on the right-hand scale of Figure 5. Included in this scale is the effect of increased generation resulting from the steam required for heating boiler feedwater to approximately 340 F.

The net heat rate on non-condensing turbines, including boiler efficiency, is approximately 4400 Btu per kwhr. Since the approximate heat rate on 850 psi condensing turbines is 12,500 Btu per kwhr, the generation of power by non-condensing turbines results in a fuel saving of 8100 Btu per kwhr. In addition, that part of the non-condensing turbine capacity which is firm or always available to meet peak electrical loads, reduces the amount of condensing turbine capacity required. The firm capacity for a non-condensing turbine using

Figure 5 — Net fuel fired steam requirements for steel plant (excluding power generation) for five weekdays, and average Saturday and Sunday.

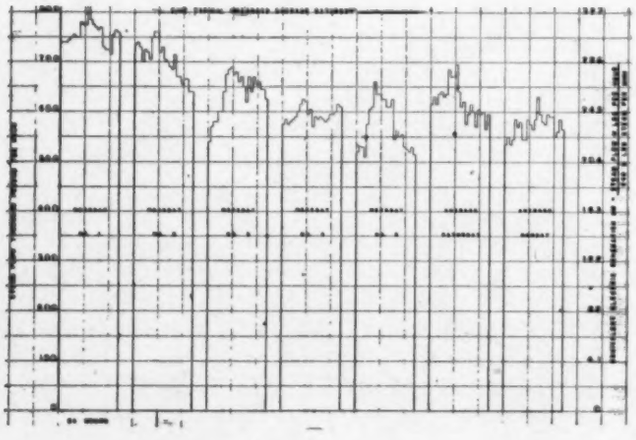


Figure 6 — Load-duration curve for fuel-fired steam requirements excluding power generation.

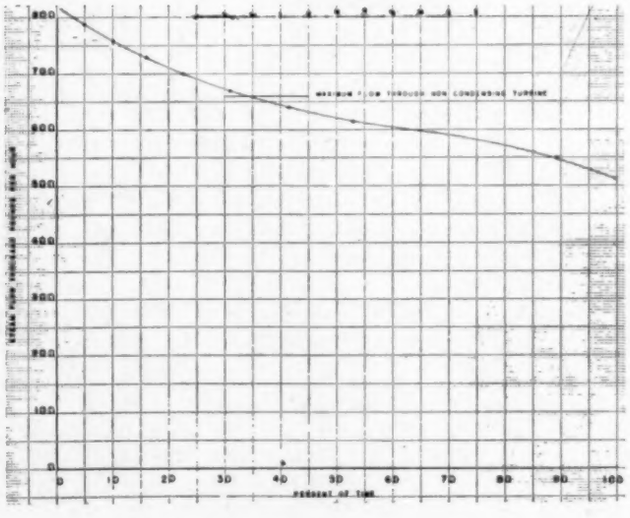


TABLE II

Comparative Costs for Three Sizes of Condensing Turbines

	Case		
	I	II	III
1. Nominal turbine rating, kw	20,000	30,000	40,000
2. Turbine capability, 1.10 x line 1, kw	22,000	33,000	44,000
3. Peak operating capacity, kw	141,000	141,000	141,000
4. Maintenance capacity = line 2, kw	22,000	33,000	44,000
5. Total required capacity = line 3 plus line 4, kw	163,000	174,000	185.000
6. Average excess capacity = ½ x line 2, kw	11,000	16,500	22,000
7. Average installed capacity = line 5 plus line 6, kw	174,000	190,500	207,000
8. Installation cost, dollars per kw	$130	$120	$115
9. Average annual investment costs = 0.12 x line 7 x line 8	$2,720,000	$2,745,000	$2,865,000
10. Annual operating hours (Estimated)	48,000	32,000	24,600
11. Fixed annual operating costs = line 10 x $3 per hr	$432,000	$288,000	$221,400
12. Total annual fixed costs = line 9 plus line 11	$3,152,000	$3,033,000	$3,086,400

To meet present load, install five 33,000 kw turbines, if plant generates entire load.

the steam shown in Figure 5 would be equal to minimum weekday generation or 20,000 kw.

Table I shows the investment costs and annual savings for three cases of non-condensing turbine capacity which could be installed. Because of flexibility in both turbine operation and power distribution (see Mr. Howry's paper) these capacities are each divided between two turbines. The capacity of the turbines installed in each of the cases would be 110 per cent of nominal rating. The total capacity for Cases I, II, and III is 22,000 kw, 27,500 kw, and 33,000 kw respectively.

The investment required for each case is that required to install the non-condensing turbines themselves and the additional investment required to increase the operating pressure and temperature of all fuel-fired boilers supplying plant steam, from 275 psi, 640 F, to 850 psi, 900 F.

The net annual investment cost for each case is estimated at 12 per cent of the difference between the investment required to install the non-condensing turbines and that required to install 20,000 kw of firm condensing capacity. These costs are shown on line 7 of Table I. The value of the fuel saved per year is shown on line 8. The unit value of the fuel saved has been set at $0.25 per million Btu.

The total net annual savings for each case are shown on line 9. The net return on the investment required to install each case is shown on line 10. As shown, two 13,750 kw turbines, would effect a net annual return of 14.7 per cent. The return on the increased investment for Case II over Case I is, as shown on line 13, 16.2 per cent. On the basis of these returns, Case II, or two 13,750 kw non-condensing turbines has been selected for installation at the steel plant.

A load duration curve for fuel-fired plant steam is shown in Figure 6. Marked on this curve is the maximum steam flow which could be bled through the two non-condensing turbines. Steam requirements in excess of this amount would be bled around the turbines through a reducing valve and desuperheating station.

SELECTION OF CONDENSING TURBINES

SEPARATE OPERATION

Figure 7 plots the total plant electric load by hours for the five typical weekdays, an average Saturday, and an average Sunday. Shown are hourly integrated loads, peak demands, and hourly integrated generation by the two 13,750 kw non-condensing turbines. The difference between non-condensing generation and hourly integrated loads is the generation which would have to be made by condensing turbines, if the steel plant generates all of its electrical load. The difference

TABLE III

Installed Electrical Generating Capacity

Steel Plant Generating Entire Electrical Load

Unit number	Type	Installed capability	Firm capability
1	Non-condensing	13,750 kw	10,000 kw
2	Non-condensing	13,750 kw	10,000 kw
3	Condensing	33,000 kw	33,000 kw
4	Condensing	33,000 kw	33,000 kw
5	Condensing	33,000 kw	33,000 kw
6	Condensing	33,000 kw	33,000 kw
7	Condensing	33,000 kw	33,000 kw
Total		192,500 kw	185,000 kw

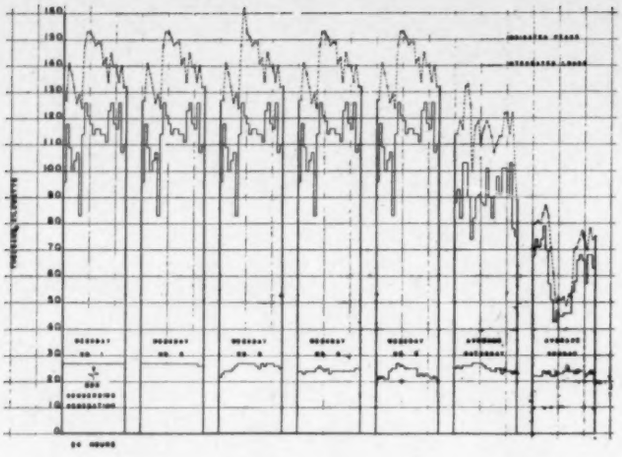


Figure 7 — The graph shows the indicated peaks and integrated electric loads for every hour of the week.

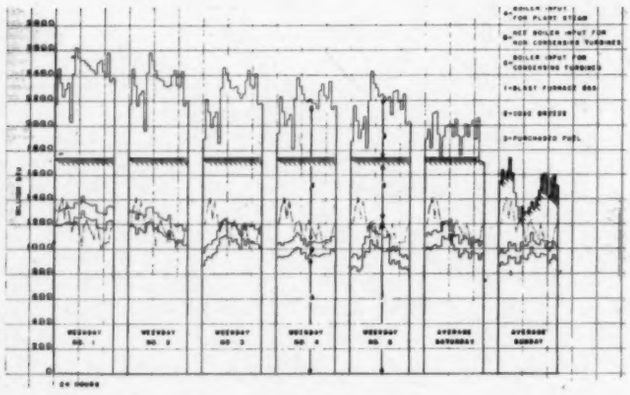


Figure 8 — Hourly heat input for steam and power generation.

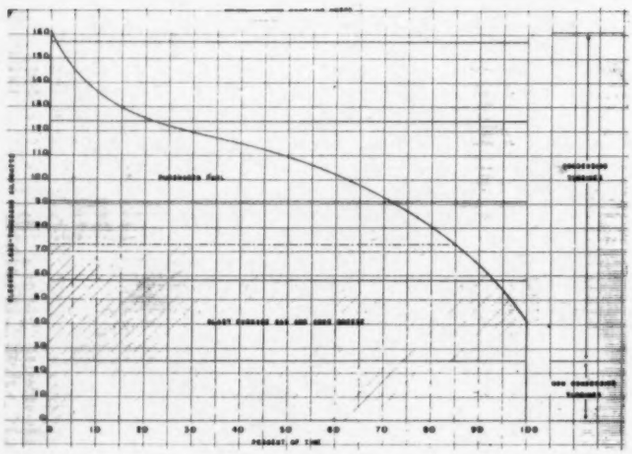


Figure 9 — Electric load-duration curve.

between firm non-condensing turbine capacity and peak electric demand is the amount of condensing turbine capacity which the plant must operate. This difference is 141,000 kw. The amount of condensing turbine capacity which the plant would require is equal to operating plus maintenance capacity. This maintenance capacity should be equal to the capacity of the largest generating unit installed.

Installed capacity must be equal to whole multiples of individual unit size and, because of this, is normally greater than the capacity which is required to operate the plant. This excess capacity represents an investment in generating quipment which is not used. The larger the individual unit size installed, the greater this excess capacity will average over any period of time in which a steel plant is growing.

Table II is a comparison of annual costs for 22,000, 33,000, and 44,000 kw turbines, any of which could be installed to meet the entire electrical load of the steel plant. As shown on line 5, the condensing capacity which is required to operate the plant at its present electrical load is 141,000 kw plus maintenance capacity equal to the size units installed. To allow for the average excess capacity which would be installed, a growth factor equal to one-half unit capacity is added to the required capacity. The resulting average installed capacity is used as a base for comparing the annual investment costs shown on line 9 of the tabulation.

The sum of annual investment and fixed operating shown on line 12 is lowest for the 33,000 kw condensing turbines. Because of this, 33,000 kw has been selected as the unit size to be installed at the steel plant.

The resulting turbine capacity which would be installed by the steel plant to generate its entire electrical load is listed in Table III. This capacity would consist of two 13,750 kw non-condensing turbines and five 33,000 kw condensing turbines.

Plotted in Figure 8 are the hourly heat inputs to the fuel-fired boilers if the plant generated its entire steam and electrical loads. Forty-eight per cent of the total input would be required for generating plant steam and fifty-two per cent for generating electric power. Blast furnace gas would make up fifty-six per cent of the total input; coke breeze, twenty-five per cent; and purchased fuel, the remaining nineteen per cent. The cross hatched line represents the portion of the total heat input which would be supplied by blast furnace gas and coke breeze.

The amount of condensing turbine capacity required in Case II of Table II to meet present peak electrical demand is 174,000 kw. Five 33,000 kw turbines would provide 165,000 kw of installed capacity; six would provide 198,000 kw. For the following reasons, five 33,000 kw condensing turbines are considered adequate to meet the plant electrical load:

1. One of the units installed is a maintenance unit which should be available approximately eighty per cent of the time to meet peak demands.
2. Peak demands occur infrequently.
3. Turbine outage could be scheduled for those times of the year when the generation on the non-condensing turbines would be greater than their 20,000 kw firm capacity.

A load duration curve for the plant electrical load is shown in Figure 9. The areas between the horizontal lines which divide this curve represent blocks of power equal in demand to the average capacity of the non-condensing turbines or the capacities of each of the five 33,000 kw condensing turbines.

As has been explained, one of the five condensing turbines is installed primarily as a maintenance unit. If the availability factor of each condensing turbine is 95 per cent, this maintenance unit would be required

TABLE IV

Installed Electrical Generating Capacity
Steel Plant Purchasing Part of Required Capacity

Unit number	Type	Installed capability	Firm capability
1	Non-condensing	13,750 kw	10,000 kw
2	Non-condensing	13,750 kw	10,000 kw
3	Condensing	33,000 kw	33,000 kw
4	Condensing	33,000 kw	33,000 kw
Total installed		93,500 kw	86,000 kw
Purchased capacity			99,000 kw
Total capacity			185,000 kw

but 20 per cent of the time to meet peak electrical loads. The remaining 80 per cent of the time it would be idle.

SELECTION OF CONDENSING TURBINES COMBINED OPERATION

If the steel plant were connected to and operated in parallel with another large electrical system, these advantages should result:

1. Diversity in scheduled outage of boilers and turbines should reduce the total capacity which would have to be installed by the combined systems.
2. Diversity between peak electrical demands of the two systems should again result in a reduction in the total capacity which would have to be installed by the two systems.
3. The increased size of the combined systems might justify the installation of fewer but larger turbines at the steel plant.
4. The units installed at the steel plant, being relatively efficient, might, when not generating power for the steel plant, replace generation on less efficient units in other parts of the system.

It is beyond the scope of this paper to estimate what these advantages would mean in terms of reduced operating or investment costs. The advantages, however, are apparent; and it is pertinent that they be pointed out.

Obviously, if the steel plant can purchase power from a public utility, it does not have to install all of the capacity listed in Table III. The decision regarding how much of such capacity to install would be based on a comparison of the steel company's cost of generating and purchasing equivalent blocks of power. To forego the possible misapplication of published utility rates for power or a comparison of hypothetical costs with a published rate based on incomparable investment, operating, and fuel costs, this paper makes no attempt to base the installed capacity for the hypothetical steel plant on a cost comparison. It limits, rather, the installed capacity for the hypothetical plant, when purchasing power, to the capacity necessary to burn all by-product fuel. The cross hatched area on the load duration curve in Figure 9 represents the part of the total electrical load which could be generated with blast furnace gas and coke breeze. As shown, this area extends into the third block of power or the second 33,000 kw condensing turbine. Table IV lists the installed capacity which results, or two 13,750 kw non-condensing turbines and two 33,000 kw condensing turbines.

SUMMARY

In this paper, the amounts of blast furnace gas and coke breeze available to a hypothetical steel plant have been shown. It has been indicated that these fuels would first be used efficiently in other parts of the plant, and the balance remaining used for generating steam and power. Coke oven gas and tar have been considered as fuels which could be used more effectively in other parts of the plant or outside of the plant rather than for generating steam and power.

The potential electrical generation which could be effected by first passing low pressure plant steam through non-condensing turbines has been shown. The full utilization of this potential generation has been limited by the amount of plant steam which can be considered as available for firm generating capacity, and the amount which does not incite sufficient return to justify the investment required for its utilization as a source of electric power.

The effect of unit size on the total electrical generating capacity which must be installed to provide maintenance reserve and to allow for the difference between maximum generating requirements and whole multiples of unit size has been illustrated in the tabulation comparing the three sizes of condensing turbines.

The possible advantages of diversity and improved turbine loading which might result from operating the steel plant power station in parallel with another large electrical system have been pointed out.

The generating capacity which must be installed to utilize the available blast furnace gas and coke breeze has been set.

These are general considerations which affect the interrelation of plant fuel balance, steam loads, and electrical loads. Other more specific considerations also affect this relation. Plant geography, engineering design of the steam and power station itself, and, in most steel plants, the limitations imposed by existing equipment, are some of the other considerations which complement or modify the application of the concepts presented in this paper to a specific steel plant.

DISCUSSION

PRESENTED BY

FRED C. SCHOEN, Plant Engineer, The Midvale Company, Philadelphia, Pennsylvania

F. O. SCHNURE, Electrical Superintendent, Bethlehem Steel Company, Sparrows Point, Maryland

G. H. GREENE, Chief Engineer, Bethlehem Steel Company, Steelton, Pennsylvania

F. H. SPIESS, Fuel Engineer, Alan Wood Steel Company, Conshohocken, Pennsylvania

L. V. BLACK, Superintendent, Electrical Department, Bethlehem Steel Company, Bethlehem, Pennsylvania

H. L. HALSTEAD, Assistant Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

A. D. HOWRY, Assistant Superintendent Maintenance — Electrical, Alan Wood Steel Company, Conshohocken, Pennsylvania

Fred C. Schoen: The plant is the kind of plant, I suspect, a great number of us have dreamed about; but, unfortunately we are operating plants quite different from that given in the paper. The thing that I am curious about is this: for the past five years, and at present, we are able to operate the plant 24 hours a day and 6 or 7 days a week, but some of our operations are going down to one shift a day, four days or perhaps five days a week. As a result of that, we will get very high loads on the "A" turn, and practically a non-existent load on the "B" and "C" turns. Under such conditions, you will have to shut down this nice, new hypothetical plant, your overhead continues, and your savings come down. Again, we have shift differentials, so you cannot take some of the operations off a shift and equalize the load, off the "A" turn, for example, and put on the "B" turn to equalize the load. I would be interested in the author's comments on how his plant would work under some of the conditions we can expect in the next couple of years. We hope we won't have them, of course, but how would this bright and shiny plant work under such circumstances?

F. O. Schnure: It is not often that the opportunity occurs to establish a 160,000 kw plant from scratch as has been done in the paper under discussion. Most of today's sizable plants started at a fraction of the present capacity and were enlarged as the demand arose for more products. Such has been the case in the plant with which I am connected and which, strange to say, will soon reach the 160,000 kw stage.

In estimating future power loads, hindsight over a number of years improves the accuracy of the forecasts. It also shows that the larger the plant, the lower the diversity factor becomes. It is also rather remarkable how consistent the peak and integrated loads are year after year, the ingot rate remaining fairly constant.

The amount of power used by the steel industry is probably more than it is casually considered to be. The December 1946 issue of the *Iron and Steel Engineer* gave very interesting data along this line which placed the steel industry as using 21.7 per cent of all the power used in the U.S.A. All industry used 52 per cent and of this 32 per cent was generated by industrial plants. Based on our plant, and assuming the normal increase in total power in the U.S.A. to follow the same curves as our plant would follow in growing to the 160,000 kw power system under discussion, our plant would use about one four-hundredth part of all the power used in the U.S.A.

G. H. Greene: While I do not think the assumed steel plant fits any particular plant in the country, the steps taken by the authors clearly indicate the correct procedure that should be followed in working out a fuel-load balance for any particular plant. This paper should act as a very good guide for anyone having this problem to tackle for his plant.

F. H. Spiess: The manner in which the authors described the power plant and developed the fuel distribution, from waste blast furnace gas and excess coke-breeze to purchased fuel oil, certainly must have entailed considerable work in correlating the data. Their position is ideal for obtaining the necessary steam distribution for turbo-blowers, generators, and auxiliaries in that meters and distribution equipment are to be provided. Most of us at operating plants have not been so fortunate because, instead of figures of a hypothetical steel plant, the problem is to obtain hypothetical figures from steel plants where distribution meters and necessary equipment to obtain such figures are not too plentiful, especially where auxiliary equipment has been added from time to time as the plant expands.

I understand that you use a cost value of "zero" for the blast furnace gas, and then establish a cost of twenty-five cents per thousand pounds of steam. Now, since you are comparing this plant with a modern public utility station, I would think the blast furnace gas should have some predetermined value so that the actual cost of steam could be used. This, of course, would raise or lower the steam cost, depending on the quantities of various fuels used.

L. V. Black: I think that the authors missed one vital point in the heat balance of the hypothetical plant. We at Bethlehem use blast furnace gas for operating gas driven generators and I think using gas for fuel under boilers is not as efficient or economical as using it directly in gas engines.

H. L. Halstead: Regarding Mr. Schoen's question, the diversity which you can carry from reducing your peaks by scheduled operations, is a question for management to decide. I think that the load duration curve made clear the large amount of investment you are carrying to carry peak loads. If management resolves to reduce that investment at the expense of scheduling plant operation from turn to turn, to reduce the peak loads, that is one way to do it. I would not be able to estimate what the savings will be, but, if you had a load to meet you would have to meet it.

Regarding the cut-back in operations over a period

of years, or, during a period of business depression, I think that that points to one of the advantages of having a public utility.

I have compared the growth curves for a steel plant against the growth curve for a public utility system. The steel plant will go up one year and down the next, and so on. The public utility system is more steady. I do not say that it does not recede, but on a percentage basis, it does not recede so much. In the public utility, the drop-off in load curve represents a delayed investment, not an unused investment. In the steel plant it represents drop in investment of equipment not used. If the two go together, you would save money, I think.

Now, regarding the 25 cents fuel saving on blast furnace gas, in any plant in which you have to burn purchased fuel, and we showed in this plant that we did, any fuel that is burned or any by-product fuel that is burned, replaces an equivalent percentage of purchased fuel. As soon as the fuel is burned in the boiler, you up-grade the value to the equivalent of purchased fuel. If your fuel cost is 25 cents, every million Btu you burn, saves you a million Btu of purchased fuel.

Now, regarding Mr. Black's question about gas engines: Most steel plants operating now have gas engines running and they are on the condensing turbines which I showed. As far as fuel goes, I have figures for gas-electric engines, with waste heat boilers installed. In the figures I have shown a heat rate of approximately 9½ Btu per megawatt hour. That is on a gas-electric engine equipped with waste heat boilers, but the investment cost in gas engines is much higher than in condensing turbines. I believe it is twice as much.

The other thing in the fixed operating cost is the labor and maintenance on gas engines which are much higher than on the larger condensing units. Installed, I think the 850 psi condensing turbines are cheaper than the electric engines if you have them in today.

Regarding the 95 per cent availability on the turbines, I am going to concede that the 95 per cent might be low for an industrial plant, but I received that figure from a report on utility practice, for 850 psi condensing turbines, and I think the availability factor as used in the utility is lower than that. If you say the availability of the turbine is 100 per cent, you do not need the maintenance unit, and I also think I emphasized the little use you get out of it from the load duration curve.

The other question was the possibility of overload on the condensing turbines. We showed five turbines necessary to carry the load. Now, if you would reduce that to four, when you would lose one turbine that would mean the load on the fourth turbine would have to be carried by the other three, meaning increasing it 33⅓ per cent on the other three turbines to meet the load as shown.

Another question was, is it worthwhile to spend that money for maintenance capacity? That is a question for management to decide. They would certainly know the money they are paying for maintenance capacity. If they want to elect to reduce load partially, it would not be much in terms of total integrated load to do so, but on the curves we had a load to meet and we attempted to meet it.

A. D. Howry: I would like to add that, as we have created a hypothetical plant, I might say we also can create all the answers. No matter what is asked, I believe we could give some kind of answer with which you would have to be satisfied.

The relative value of blast furnace gas has been adequately covered by Mr. Halstead's comments. It is a question I heard the first day I was with the steel company, and I have heard the same within the last 24 hours. It is a question we will always have with us. That blast furnace gas does have a value is unquestionable. The value is like our paper; it is hypothetical and must be based on the plant heat balance. If you do not have the gas, you must purchase fuel, so the practice has been to evaluate the gas at the equivalent cost of purchased fuel to supply the power necessary.

I would like to add one thing. In our paper we say we get an integration of energies in the steel plant operation that we do not have in other industries; blast furnace gas is one of these energies. We may evaluate the cost of this fuel at a bookkeeping figure at any value, but in the last analysis, it is money in the company's pocket, revenue that we do not have to pay to outside sources for equivalent fuel.

H. L. Halstead: All industrial plants have an electrical load which varies with operating turns and periods of changing business activity. Electrical generating capacity must be provided to meet these peak electrical loads. This paper assumed that the electrical generating plant would be designed to meet the electrical load; not that plant operation would be scheduled to reduce electrical peaks and thereby reduce the required electrical generating capacity.

The value to an industrial plant of any by-product fuel which is wasted is zero. The value of this fuel when used to replace purchased fuel approaches the value of purchased fuel. An accurate comparison of the relative values of several fuels would of course take into account the differences in capital costs for equipment to burn the several fuels, the differences in operating costs exclusive of fuel, and the differences in thermal efficiencies.

The distribution of costs and credits for by-product fuels between the several departments of a steel plant is an interdepartment accounting problem. Whether or not this distribution is equitable should not deter any plant from taking full advantage of the economies afforded by by-product fuel utilization.

It is true that the over-all thermal efficiency of gas engines, particularly those equipped with waste heat boilers, compares favorably with condensing turbines operating at 850 psi pressure and 900 F steam temperature. Gas engines however have these disadvantages: their installation cost is higher, their operating cost exclusive of fuel is higher, and they do not have the flexibility for multi-fuel firing which a boiler-turbine installation possesses.

I appreciate the fact that few if any industrial plants ever have the opportunity of completely redesigning their entire steam and power generating facilities without consideration of the limitations imposed by existing equipment. Most steel plants, however, have the common opportunity of utilizing by-product fuel and supplying process steam from the exhaust of non-condensing turbines to effect considerable saving in the cost of generating electric power.

Surface Activity of Lubricants

. . . . the phenomena of surface activity may, upon future study, provide the answers which will explain lubricant behavior . . . .

By J. M. WILSON

Products Application Department

Shell Oil Company

Wood River, Illinois

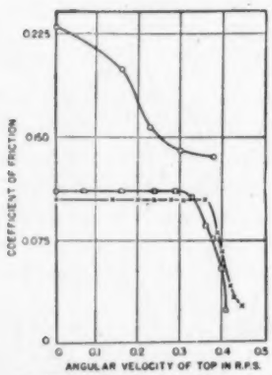


Figure 1 — The curves illustrate the variation in friction with velocity.

▲ THE practice of lubrication and the degree of success attained therein depended for a long time on the observations of the results obtained. Little information was available to explain these results and engineers had to rely for the solution of new problems on past experience in supposedly similar situations, or on guesswork. In an attempt to improve this situation, we are accumulating a great deal of knowledge about the "why" of lubricant behavior in many respects, and it is the purpose of this paper to discuss surface activity as one of these factors in the light of its relation to some of the performance aspects of lubricants.

The behavior of lubricants and their suitability for most of the applications in which they are used are very largely determined by the properties which constitute their surface activity. In stating this fact, it is well to define the term surface activity as we intend to use it. This will be a broad definition and refers to the behavior of lubricants at the interface where they are in contact with other materials in service. Since this is such a broad definition, we will gather in the boundaries of the field and limit the discussion to some of those phases of surface activity which are of practical interest and significance.

In the group of materials classified as oils, there exists very wide extremes of surface activity. For example at one end we have the petroleum white oils, which show very little activity toward other liquids or solids, and through an infinite number of graduations we pass to the fatty oils and additive bearing materials of various types which are very active. In order to understand the significance of the phenomena involved, some discussion of the manner in which they are manifested will be helpful.

If a drop of medicinal white oil is placed on a piece of metal, it shows little tendency to spread or to wet the metal. If this same type of oil is mixed with water, it will be found to separate quite readily with no emulsifying tendency at the interface. Friction values between two metal surfaces separated by a film of white oil will be relatively high. If a small amount of fatty acid, such as oleic acid, is now added to the white oil, its behavior will be found to have changed markedly. It will wet or adhere to metal much more readily; the tendency to emulsify in water will be greatly increased; and the reduction in friction between metal surfaces will be much greater. See Figure 1.

All of these changes in behavior are a result of surface activity. The acid-free white oil is made up almost entirely of paraffin hydrocarbons which are chemically saturated and contain none of the chemical groups that are active. Consequently, the oil has little tendency to react or mix with other substances. The fatty acid on the other hand contains chemical groups which are relatively very active, are soluble in oil, and show a tendency towards solubility in water. This activity results in a concentration of molecules at the interface, which in contact with water have a tendency to dissolve in water as well as in oil, resulting in the formation of an emulsion. In contact with metal surfaces, the active molecules have been shown to orient themselves with their length perpendicular to the surface and with the active chemical groups attached to the metal[1]*. The exact mechanism of this attachment and of the effect on friction has not been determined. Much of the evidence [2, 3, 4, 5] indicates that a chemical bond is formed with the metal and that the concentration of active molecules oriented in a definite pattern on the surface greatly increases the ease of slip of the molecules rela-

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* Numbers refer to bibliography at end of article.

tive to each other. Electrical resistance measurements between surfaces have proved the establishment of a "wedging" effect when surface active compounds are present[2] and such an effect is manifested when very low concentrations of active materials are present in lubricating oils. In the writer's opinion this is brought about by the solvency of the relatively inactive oil for the hydrocarbon portions at the free end of the active molecules. In other words, the formation of a very thin, possibly monomolecular, layer of active molecules on the metal surfaces conditions the metal, so that it can be more readily wetted by the oil. That this is the case is indicated by the findings of many investigators in the field of lubrication who have reported erratic results in friction measurements because of the difficulty of completely removing active materials from the surface of test pieces. Figure 2, which was drawn to illustrate the action of rust preventive oils, shows diagrammatically this surface active behavior of polar materials in lubricants.

From this very brief description of the nature of surface activity in lubricants as related to friction, it is apparent that there can be many resultant effects on their behavior in service. What is perhaps the most important of these effects, the "oiliness" or lubricating quality of oil apart from its viscosity, has been recognized as a surface activity phenomenon for many years and has been the subject of much study. As advancements have been made in operating technology and in the design of equipment, the demands on lubricants have become more severe in many respects and changes have been made to meet these demands. With these changes we have become more conscious of the part of surface activity and have learned a great deal about making better use of it. For example, the lubrication of oil film type roll neck bearings calls for an oil of quite good stability in order that it can be used for an economically long period. We know that the best way to obtain long life in petroleum oil is to refine it to a very high degree and then to add a suitable oxidation inhibitor. Our knowledge of surface activity has shown that in refining very severely we remove not only undesirable constituents of the crude oil but also those compounds which give surface activity or "oiliness." Consequently, we must refine to the optimum degree that results in a suitable balance of stability for long life, "oiliness" to provide adequate lubrication for sleeves and journals, and minimum tendency to emulsify. An attempt to improve one of these qualities beyond the balance point will result in a loss of performance in the others.

It should be mentioned here that control of refining technique does not afford our only means of varying the surface activity of oils. There is first the choice of oil origin, whether animal, vegetable, or mineral. Economics, as well as other factors, limits the bulk of lubricants for industrial uses to those of petroleum origin. Crude oils vary widely in their characteristics, but modern refining methods permit us, within economic limitations, to start with almost any charging stock and refine to similar finished products from each. Through a combination of systematic research and empirical methods, it has been learned that the behavior of refined oils can be controlled in several ways by the incorporation of additives. The terms "addi-

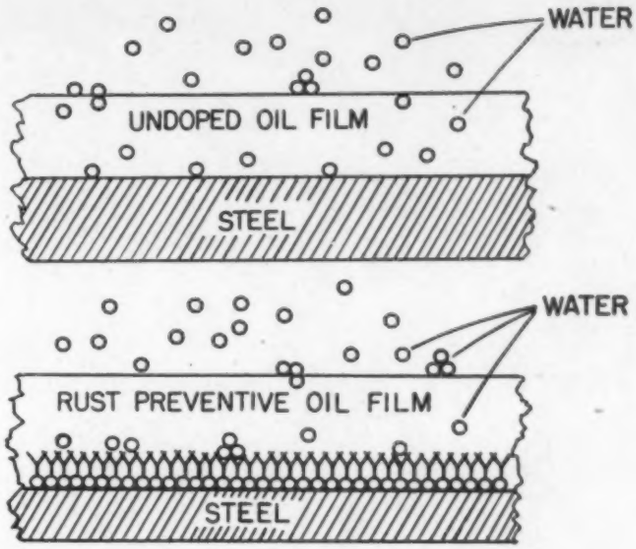
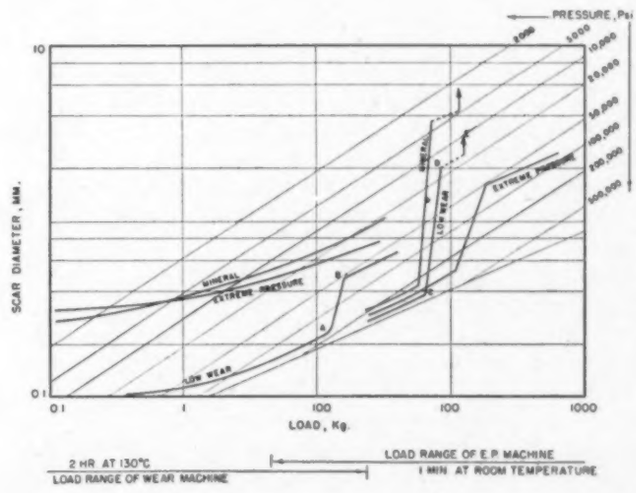


Figure 2 — Polar compounds increase surface active behavior, probably by concentrating on the metal surface.

tive," "blending agent," or "compound" may often be used in somewhat the same sense, but in the petroleum industry we usually differentiate between these terms simply on the basis of quantity. An "additive" is effective in small amounts, as little as a few thousandths of a per cent, and usually refers to materials used in percentages up to about five. Beyond this value the non-petroleum component becomes quantitatively a large part of the product and is more frequently referred to as a blending or compounding agent.

The load carrying ability of a system under certain conditions can be increased by the incorporation in the lubricant of certain surface active ingredients. There is a relatively mild requirement in this respect exemplified by such applications as the slides of some machine tools. Where surfaces move slowly and under heavy load, it is sometimes not possible to maintain a continuous film with undoped mineral oil. The addition of surface active

Figure 3 — These curves give test results, from 4-ball wear, and extreme pressure testers, on the behavior of straight mineral, low wear, and extreme pressure oils.



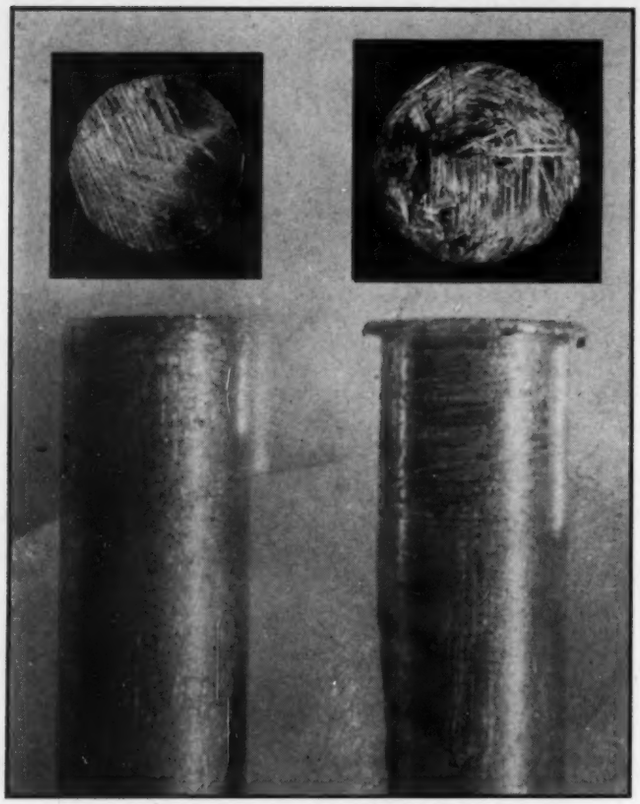


Figure 4 — Wear was induced on these steel pins by rotating steel disks; and the effect of a chemical polishing agent on a reactive metal is shown by a comparison of the pin on the left which was lubricated with white oil plus 1.5 per cent tricresyl phosphate and that on the right which was lubricated with white oil only.

agents, which can be of several types in such a case, results in establishing very satisfactory lubrication.

A more severe requirement, and one which is encountered quite frequently, is that involving the use of "extreme pressure" agents. We sometimes refer to "mild e.p." and "true e.p." conditions. Each represents basically the same thing, but the requirements for satisfactory handling may be different. Under these conditions the loads and speeds are such that a film of mineral oil will immediately rupture, and extremely high rates of wear or actual metal seizure occur. A simple wetting or oiliness agent is not adequate under such conditions, and it is necessary to use an e.p. compound. These are truly surface active materials in that they perform their function by reacting with the metal surface involved under the high temperature conditions induced locally to form a film of anti-weld compound and prevent the severe scuffing and galling of rubbing surfaces. The most commonly used materials for this purpose are sulphur and chlorine, carried in a loosely held chemical combination that will permit their reaction to form sulphide or chloride films at the temperatures induced by extreme pressure conditions.

This explanation of the manner in which e.p. lubricants function raises a question as to the effect of the formation of a chemical film on the subsequent performance of the metal and the lubricant. There is some consumption of the active ingredients of the lubricant and some removal of the metal surface, but in almost all cases the effect is very slight. There is, in fact, very good evidence to indicate that the resulting wear is beneficial and in the nature of a "break-in," as many installations have been encountered of bearings and gears where e.p. materials are found unnecessary after an initial period of operation with their use. Figure 3 presents some idealized curves showing the behavior of straight mineral, low wear, and extreme pressure oils under different loadings.

The foregoing brings us to consideration of another manifestation of surface activity of lubricants, that of break-in additives and chemical polishing agents. Such materials serve the purpose of enhancing the lubricating qualities of an oil until the surfaces in a new installation are properly conditioned, or of actually hastening the conditioning by inducing wearing-in under controlled conditions. The former case is simply that of providing an increased amount of "oiliness" through the addition of fats, fatty acids, or similar polar materials. The use of chemical polishing agents is much less widely practiced, and in fact is still under study, although a good idea of its potential possibilities may be gained from the studies reported in reference 6. The action of these materials is similar to that described for e.p. agents in that they react chemically with the metal surfaces. However, the compounds formed in this case are apparently either removed, or serve to smooth out the minute irregularities in the surfaces, but do not leave an anti-weld film as with the e.p. compounds.

So far, the surface active phenomena discussed have dealt largely with the improvement of lubrication by reducing friction. Another very important function of lubricants is the prevention of wear. This is, of course, closely tied in with the reduction of friction in many cases; however, Larsen and Perry[2] have made very extensive studies of friction and wear separately and have reported quite significant findings. In the region between fluid film lubrication and true boundary lubrication, wear is found to be markedly reduced by certain compounds, notably some containing sulphur and phosphorus. Among those compounds, the ones having the highest degree of surface activity were most effective in reducing wear. It is postulated that this results from the establishment of a concentration of the active materials at the metal surfaces because of the tendency of polar groups in the compounds to react with the metal. Unfortunately, the compounds which are most effective in reducing wear and those most effective in reducing friction appear to compete with each other for a place on the metal surface, to the detriment of each when they are both present. We have therefore the problem of learning how to take advantage of what we know about these materials to get the beneficial effects of both simultaneously.

While friction and wear are highly important surface activity phenomena, another function of lubricants having almost equal importance is that of protection against corrosion or rusting. This is a manifestation of surface activity which may occur in either of two ways. One is a matter of conditioning the metal surface so that it is more readily wetted by oil, and the behavior is very similar to that described previously with reference to improvement of "oiliness." In the case of surface protection, however, the choice of active materials is usually more critical, as the applications frequently require that the stability and demulsibility characteristics of

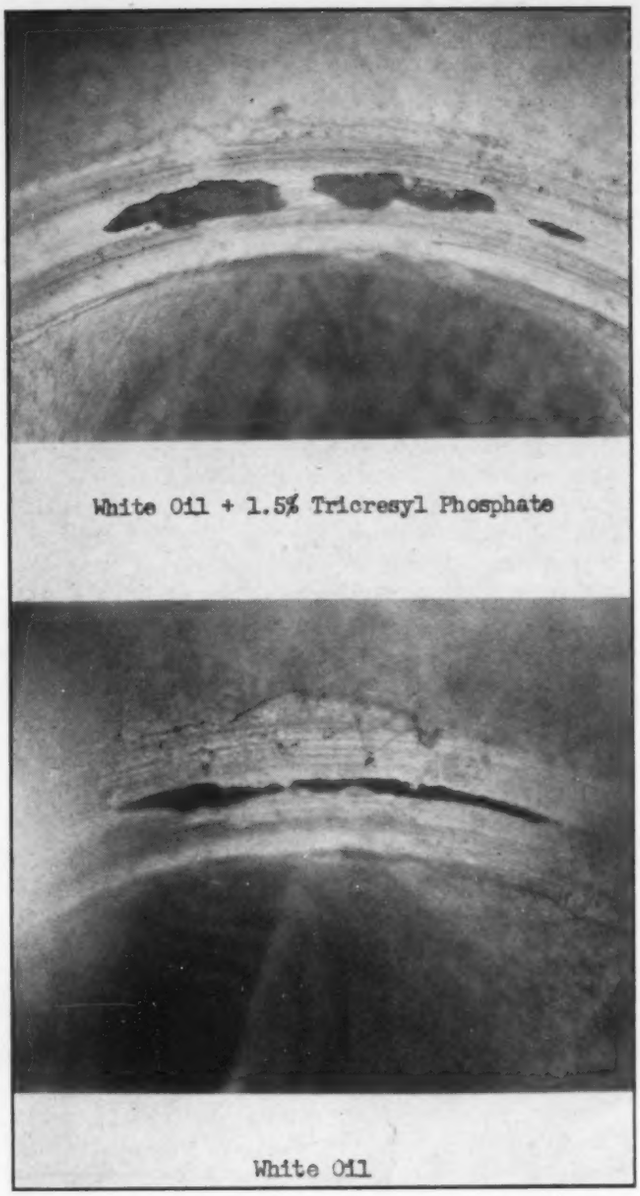


Figure 5 — A chemical polishing agent is relatively ineffective when used on a non-reactive metal as is shown by the wear tracks on these two gold-plated bells.

the oil must not be diminished. Corrosion protection of this type is referred to as bulk protection, where a small amount of the active agent is present and depends for its effectiveness on a continuous supply of the oil in which it is carried. Von Fuchs[7] has discussed corrosion prevention by this means.

The second means of corrosion prevention using lubricants is that of film type protection. This may involve purely mechanical protection by the use of a durable film of asphaltic or similar material, in which case surface activity plays little part. On the other hand, many of the most effective corrosion preventive lubricants, particularly those of the thin film type, depend on the presence of a high concentration of very active polar materials. Many of them are sufficiently active to form a film of oil on metal surfaces in the presence of water, displacing the water and thereby protecting the metal. Again, the action is similar to that of the oiliness agents in that a layer is formed next to the metal surface which has an affinity both for the oil and for the metal, resulting in increasing the tenacity with which the oil film is retained (Figure 2). Pilz and Farley[8] report some interesting studies of the phenomena involved and of a simple method of evaluating many of the surface active corrosion preventives.

Surface activity of lubricants again is manifested in the emulsion characteristics of oils. For many applications we desire the oil to be free of any tendency to emulsify. Freedom from surface activity gives this result, but it may be attained at the expense of other desirable qualities. On the other hand, for lubricating conditions where moisture is present as in wet steam or compressed air, we deliberately add certain fats or other agents which promote emulsification by their surface activity. The so-called "soluble" oils used as hydraulic media and in metal rolling and machining represent the extreme in emulsifiable oils.

In the field of metal working there are many applications which appear to involve the surface activity of lubricants. Cutting, stamping, and drawing usually require materials having characteristics different from those of straight mineral oils, and the nature of the compounds that have been used successfully leaves little doubt that surface activity is involved. In spite of a great deal of study of this subject, much is yet to be learned, and practice today is largely based on empirical knowledge. Metal rolling, tinning and quenching use lubricants in which surface activity seems to play a part. Again much is yet to be learned about the functions of the lubricants here, but the variations in results that can be obtained by changing the composition of the oils support the probable importance of surface activity.

There are many other applications of lubricants in which surface activity plays an important part but which are of less interest than some of the foregoing in lubrication engineering. There is also doubtless very much more to be learned about the surface activity of lubricants and its significance, and much effort is being expended in acquiring this knowledge. What has already been accomplished in this direction has been very useful and profitable and certainly justifies our continued studies and observations.

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DISCUSSION

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N. I. Whiteley: The steel industry probably utilizes more of the extreme pressure and oxidation inhibitor type of oils than any other industry. I have spent a great many years in the oil industry and have followed the gradual evolution in oxidation inhibitors and extreme pressure qualities both in the industrial and automotive fields.

The paper is divided into five parts. The first part concerns the use of oxidation inhibitors. In oxidation inhibitors the steel industry and lubrication engineer have to be more or less dependent upon the oil company as to what they should use. My personal concern in regard to oxidation inhibitors is the type used in the oil, and how it is going to react with some of the foreign material that contaminates the oil in the steel mill.

Mr. Wilson's paper deals with the oil film type bearing with which we are all familiar due to its wide use in rolling operations. On this type of bearing, circulation systems are generally used. Oxidation inhibitors have proved of great value in these systems by prolonging the life of the oil. These systems hold anywhere from 1000 to 15,000 gallons of oil, and the cost of oil in them is high. If you had to replace the oil frequently due to contamination or oxidation of the oil, it would be quite costly. Surface active lubricants have been of material benefit in this connection.

As stated before I am concerned about the type of oxidation inhibitor and how it reacts with contamination materials. For instance in Cleveland, most of the steel mills use Cuyahoga River water, which is far from pure. Experience has shown that this water leaking past bearing seals and contaminating the oil in the circulation system has formed emulsions that were practically impossible to break. If an oxidation or surface active material is added, and it is of such a nature that water will not separate from it, trouble will result.

In recent years there have been a number of companies that have gone to the use of demulsifiers, and some of these demulsifiers react differently with the oxidation inhibitors of different companies. The only way the steel companies have to find out just what these reactions are is by actual laboratory test with various demulsifying agents and with different companies' oils employing different oxidation agents.

I have never felt, until I read this paper, that an oxidation inhibitor was a surface active material, because I always thought an oxidation inhibitor was something which prevented the general oxidation of the oil and acted on the oil itself. Mr. Wilson described it as something that acted on the surface of the metal. That was a little bit new to me.

In regard to extreme pressure agents, lubrication engineers have had much experience. In Mr. Wilson's paper he mentioned chlorinated and sulphur combinations in loose formations.

There are some chlorinated and sulphurized e.p. lubricants on the market today which are in more of a chemically stable form than others and I have successful experience with these. There are some, however, where chlorine particularly, is in such loose chemical formation, that it dissipates very rapidly and under normal dry conditions would not cause trouble.

If a large quantity of water gets into a system with this type lubricant, you are headed for corrosion trouble.

It is known that chlorine does help the action of sulphur by bridging over the gap until the sulphur reacts. When an oil film breaks down, the chlorine acts as an e.p. agent until the temperature is high enough for the sulphur to react. If you would draw a curve from an extreme pressure test machine you would have a very high peak where the oil film broke, then the curve would flatten out due to the chlorine which acts first and then the sulphur which reacts later. Many laboratory tests have proven this.

Another interesting topic that I have found in Mr. Wilson's paper was the use of lead naphthanates. Steel mills probably use more lead naphthanate materials than any other industry, particularly for gear lubrication.

In the lead naphthanates in general use, Mr. Wilson stated they rely upon their surface deposition which has a cushioning effect. I believe lubrication engineers are familiar with that fact, but some lubricants will deposit to such an extent that bearing feeds on the system are apt to be clogged and cause trouble.

I believe oil men are all familiar with the increase in viscosity of these lubricants. Under the pressures under which the oil operates we note considerable increase in viscosity with most e.p. lubricants. The general practice is to cut the viscosity with a lighter oil so the viscosity is maintained. The steel mill has to rely upon the oil companies to check things of this kind unless they have this equipment in their own laboratories to determine the point at which the oil is too heavy and how much to cut it.

In regard to the chemical polishing action about which Mr. Wilson spoke, it is recognized that lead naphthanates have a polishing action on gear teeth. If gear teeth become badly worn due to the use of a straight mineral oil under heavy loads, it is possible to polish out the gear teeth with the use of a lead naphthanate

oil so that they will continue to run for years afterward. Many gears have been saved in this way.

I do not believe that is a chemical polishing out action. It is rather that we have eliminated the wear and friction, and the cushioning action between the gear teeth and normal wear of the gears have finally worn the gears smooth enough that they can still operate.

I believe that further improvements in surface action lubricants and new developments by the oil companies should give us more extreme pressure qualities and more polishing action which will result in better lubrication.

Paul J. Doyle: I would like to review some of the results observed in steel plants by the use of lubricants containing surface active additives and compounds. In practice, we know there are many disturbing factors which influence the surface activity of lubricants during operations, perhaps the condition most often encountered is contamination of the lubricant, bearing surfaces and gears, with water, scale and dirt. Another frequent problem with which we are faced is the use of improper cleaning materials on bearings and gears, that often leaves an undesirable film on the surface of metal, which retards or prevents the desired surface activity of the lubricant when the unit is put in service.

The lubrication of steam engines provides another example of how the surface activity of lubricants is affected in practical application. We all know the purpose of using "compounded cylinder oils" for steam engine lubrication is to obtain a suitable degree of emulsifying and wetting out of the petroleum oil in the presence of moisture in the steam. Under normal conditions the expected results are obtained, but, if boiler carry-over is encountered, it reacts chemically with the compounding of the oil to such an extent that in many instances the emulsifying qualities of the oil have been reduced to a minimum.

I would also like to mention that additives used to improve the surface activity of lubricants for coke gas boosters and exhausters, would likewise be chemically affected by the infiltration of the gases and their products into the lubricating oil system.

Of particular interest is that part of the paper covering "oiliness and extreme pressure" characteristics of a lubricant "as two separate and distinct functions" of surface activity. Results obtained from experiments on the development of a roll oil have shown that a dual function of surface activity, that is, oiliness and extreme pressure characteristics, can be incorporated in an oil by subjecting the oil to a controlled oxidation process. It is the writer's contention that this phenomena of "dual" surface activity is the result of a complex reaction of the oxidation activity of the oil in the presence of certain metals. In the early stages of the oxidation process, oil soluble organic acids, alcohols, esters and carboxylic compounds are produced in sufficient quantities to provide the main body of the oil with the desired "oiliness" properties. However, by reason of using certain metals as catalysts to promote the oxidation reaction of the oil, corresponding metallic soaps will also be formed by a further combination of the free and combined acids and the metals present. These last formed metallic soaps then provide the desired extreme pressure characteristics to the oil along with the oiliness properties.

E. S. Carmichael: Mr. Wilson's paper on "Surface Activity of Lubricants" is, in my opinion, a concise, accurate and lucid review of some of the various concepts of boundary films as related to lubrication. Inasmuch as this paper is a resume of recorded information, together with service observations, it might be advisable to point out that some valuable fundamental work on boundary films has been carried out by F. P. Bowden and his associates at the Laboratory of Physical Chemistry, Cambridge, England. To date, most of this work has been reviewed in the Philosophical Transactions of the Royal Society of London. No attempt will be made at this time to review any of those publications, but, it is felt that some in this group might be sufficiently interested therein to refer to one or more of these articles at a later date.

As pointed out by Mr. Wilson, film strength, wear preventive characteristics, and rust preventive properties of a lubricant can be markedly improved by the use of additive materials. We would like to emphasize the fact that considerable care must be exercised in the use of additives in lubricating oils, for the improvement of a given characteristic by the use thereof might be more than offset by some deleterious effect which might result. As an example, the film strength properties of a given lubricant might be greatly improved by incorporating therein a small percentage of an additive material. The use of this particular additive, however, might modify and accelerate chemical reactions and cause the formation of sludge in the lubricating system. An additive material should not be added to a lubricant unless its behavior and characteristics are fully understood, and unless extensive testing in the field has shown its use to be suitable for a given application.

It is rightly implied in this paper that surface films during conditions of boundary lubrication are, in general, highly complex. The exact nature of these films is dependent not only upon the compositions of the constituents of the lubricant and the metal involved but also upon the operating temperature level at which the films are formed. As operating conditions change and higher boundary temperatures result, the compositions of these films likewise are altered. It may be of interest to point out that considerable work has been carried out on the nature of the boundary films through the use of electron diffraction patterns. As an example, it might be stated that some years ago, using this technique, Messrs. Simard, Russell and Nelson of Battelle Memorial Institute were able to establish the nature of some of the constituents of the boundary film which is present on bearing surfaces when leaded lubricants are employed under relatively high pressure conditions. The use of electron diffraction patterns for the study of boundary films is mentioned at this time simply to indicate that there are tools available which can be and are being used for the investigation of the nature of these submicroscopic films which occur during boundary lubrication.

George F. Bowers: It is in this field of lubrication that the most work is being done and where there is the greatest need for work. While much progress has been made, it has been to a large degree, done by the so-called "cut and try" method. Fundamental research must be continued to secure more of the basic reasons regarding surface activity.

Another phase of the subject covered by this paper

is encountered when the surfaces to be lubricated are given special treatment. This may be done for various reasons, such as aid in break-in, and when done increases the possibilities of surface activity and affects the requirements of the lubricant. Here again we shall be confronted with the same problems of film strength, reducing friction, reducing wear, and supplying adequate rust protection.

As Mr. Wilson has pointed out, what is desirable for one of these conditions may be undesirable for one of the others. With added knowledge and experience it is expected that the right additives in properly selected base stocks will result in products that will give optimum performance.

A. E. Cichelli: We readily agree that research has done a good job and should continue along with studies on surface activity. Herein is the heart of lubrication, and the more that is known of surface activity at the interface, the better can the oil companies serve us in industry. The knowledge of what action goes on in this critical zone is of utmost importance to lubrication engineers who not only specify lubricants, but have to contend with the metal surfaces and contaminants as well.

Mr. Wilson speaks of active chemical groups of polar compounds attaching themselves to the metal and how evidence indicates a chemical bond. It was also stated that active molecules orient themselves in definite patterns on the surface. Could the author be more explicit? To what active chemical groups is he referring? Is there a general classification of these? What polar groups does he mean?

Mr. Wilson indicates that there is much evidence pointing to chemical bond at the interface. Do not surface tension of the oil and the phenomenon of adsorption have any bearing on surface activity?

W. A. Smiley: In the use of lubricants it has been observed that wetting of a metal surface varies with the composition of the metal. For example, high-lead alloys seem to have a higher affinity for a lubricant than those containing nickel, chromium, aluminum and the like. When dissimilar alloys must be simultaneously wet, such as shaft and bearing, worm and gear, etc., the problem of lubrication becomes involved. Further, when the film of lubricant is broken due to prolonged pressure without motion, we are dependent on an anti-weld condition of the contacting surfaces, if scuffing and galling are to be prevented. We would be pleased to learn of any work done on this problem.

R. A. Kraus: In your paper you mentioned chemical polishing by virtue of addition agents. While you did not specifically mention any particular material, I assume you are referring to materials such as tricresyl phosphate, and triphenyl arsine and other phosphorous or arsenic compounds.

We are familiar with the chemical polishing that takes place when using carbon steel on steel combination, but I would like to inquire if you have had experience with these products in aluminum or bronze bearings, or with stainless steel shafting, or with chromium plated bearings. Is this material effective in obtaining improved surface finish with any or all of these alloys as well as with carbon steels?

Mr. Whiteley referred in his discussion to the thickening which occurs in lubricants compounded with lead naphthanate soaps. I would like to know if this thickening is caused primarily by oxidation or whether some other phenomenon is the basic cause for this reaction.

J. M. Wilson: With reference to Mr. Whiteley's remarks, there is, of course, almost an endless number of things with which one has to contend in certain problems in lubrication. This business of contaminants can cover the field from one end to the other. It is just one of the points that emphasizes the need certainly for cooperation between the plant's lubrication engineer and your lubricant supplier. We suppliers cannot foresee the exact condition that we are going to run into in every application. We try to know, insofar as it is possible and practical to do it, but of course all of you appreciate that we certainly cannot hit conditions on the head completely every time.

Mr. Doyle has mentioned that same subject, and with particular reference in his illustration to boiler compounds and steam cylinder oils. Those of you who operate your own coal mines certainly have the most outstanding example of that thing of which I know. We have been in places where you sail along in the spring with a lot of rain, with no trouble at all, and everything goes fine. Along about the end of July or August, when your ponds begin to dry up, you get into endless trouble with lubrication. We find, of course, that in the meantime you have pretty well lost your source of water and are sucking about as much mud out of your reservoir as water. The treatment has to change, the stuff that goes in your boilers, and the stuff that primes over with the steam also changes, and you have a constantly changing condition which has to be met or has to be tolerated. We, of course, try to do what we can. We hope again that we can have cooperation between the operators and the lubricant suppliers that will be helpful to all concerned. I know it is quite a problem, and it is one that we have scratched our heads over quite a bit. No doubt you fellows have done that.

I apparently gave the wrong impression about the behavior of oxidation inhibitors. I mentioned this point of sleeve type bearings and their lubrication in the paper as merely an illustration of the sort of thing that requires changes in the manufacture of lubricants. In that, or in any other circulating system where you use an appreciable volume of oil, you fellows need oils that will stay with you for a long time, something that is going to be economical to buy and to use. In order to attain that, we have to provide the best possible stability, and, for that particular application, the best possible demulsibility. That requires that we treat the oils in the refinery to the optimum degree, and then add our oxidation inhibitors, if the conditions require that. Oxidation inhibitors are there for the purpose of providing a better oil for you. Their activity is not one of those things that we think of as a surface active phenomenon in that it affects the behavior of the oil on metal surfaces or against water. Most of the oxidation inhibitors, at least those of which I know, are relatively inactive with respect to polarity or surface behavior.

Again, I was perhaps not sufficiently explicit about this business of sulphur and chlorine loosely held in e.p. agents. When I said loosely held, it was purely relative. Those of you who know about the first e.p. compounds we tried to make, know, and I think you are still finding

particularly in some cutting oils, there have been oils made up which merely carried flowers of sulphur in suspension. That, of course, is the extreme in loosely held sulphur. You have sulphur only in suspension in that case, or to a limited extent in solution in the oil. We all know that is bad in many respects. One gets abrasive action from the sulphur, and there also is a much greater tendency, if lead compounds are present, or under certain conditions of usage, for the precipitation of sulphides which may be objectionable.

I might mention, in that connection, that these lead "soap" deposits, which Mr. Whiteley mentioned, or deposits you get with the use of lubricants containing lead soaps, are quite frequently lead sulphide deposits. We have learned through sad experience that there are some lead compounds which are not too stable in oil suspension. They are not always in solution, but lead naphthenate is the best of them that we know so far in that respect. Lead naphthenate is reasonably soluble in oil, and if it is not used in excess, difficulty of separation does not occur. Some of the lead soaps do separate and one may get deposits there. On the other hand, combinations of lead with certain types of sulphur materials result in the formation of lead sulphide, and it is possible that you may get that to the extent that it becomes objectionable in the system.

At the other extreme, from the presence of free sulphur, there may be sulphur or chlorine compounds held in combination in the additives to the extent that no beneficial effect is derived from them whatever.

There has been a great amount of work done between those two extremes, and some of the most recent developments have given us compounds containing chlorine that is sufficiently active to provide the e.p. that we want, without resulting in corrosion, even in the presence of moisture, under, let me say, conditions of some of the e.p. testing machines.

Some of those materials have been used in mill service and with no untoward results. How far we can go in that respect is still to be learned, but it is one of the things on which we are gaining additional knowledge and on which we are making improvements.

Again, on the question of viscosity increases, when I spoke of viscosity increase under pressure, I meant to refer to a different thing than I believe Mr. Whiteley had in mind in his comments. We know that pressure results in an increase in viscosity with certain oils, and more so with some than with others, but this is a behavior apart from the thickening that occurs in the lead naphthenate type of materials or any soap-containing materials.

The thing that we are thinking of here, in pressure viscosity coefficient, apparently results from actual compressibility of the oil or an increase in density of the oil. In other words, it is, to draw an analogy, just as if you were to take a gas and compress it to the extent that you had a liquid. Certainly there is sufficient difference between the viscosity of liquid and gas to illustrate the point. You get a thickening-up tendency due to the increased density of the oil.

To remark further on the lead naphthenate types and to answer the question with respect to why this happens, it is a result of the catalysts of the lead soap on oxidation of the oil. All metals in common use have a certain effect toward promoting the oxidation of oils. This effect is more pronounced if the metals are in solution than it is if the metal surfaces are merely in contact with the oils, although it occurs to some extent even there. Through some means purely as a catalyst, without entering into the reaction, lead soap and other soaps act as oxygen carriers to promote the oxidation and the thickening of the oil.

These chemical polishing agents, again I am going to try to answer a couple of questions at one time here, do include tricresyl phosphate. That is one on which we first worked, and with which I believe most work has been done by others as well as ourselves. We found further that materials which behaved similarly to phosphorous in alloying with certain metals give a somewhat similar behavior. Examples are arsenic and antimony. We have accomplished very much the same thing with arsenic and antimony compounds as can be accomplished with phosphorous.

I cannot tell you with just what metals you can get this behavior. I know you do not get it with gold, not that that has any practical significance to anybody, but it is for the purpose of illustrating that those metals which do not alloy readily do not give this chemical polishing effect. We have done experiments with our four ball e.p. apparatus, in which we used goldplated balls and attempted to get this chemical polishing effect without any success. Somewhat the same wear occurs on goldplated balls in this test when using the polishing agent with ordinary straight mineral oils.

I want to thank Mr. Doyle for his further reference to development of oiliness and e.p. activities in roll oil. I think that is something that is worth our further attention and perhaps we and some of you people some day will be able to benefit by some further study of that.

Bowden and his co-workers have, I believe, done as much as any other group of individuals on this general subject of lubrication under high pressure conditions and on studies of the surfaces and surface effects in lubrication.

The same thing goes for the X-ray diffraction studies. We have some references to that. I am glad to get these others, and to know that work has been done at Battelle on that subject. That has been one of the most enlightening things from the pure researchers. It has been quite helpful to those of us who attempted to translate the things they have found to something that is effective.

Mr. Bowers mentioned the preconditioning of surfaces for e.p. activities. There were some other comments on the use of chemical polishing and e.p. additives for maintaining units in service that appeared just about to have come to the end of their rope. This preconditioning has been shown to be related to e.p. activity in that some workers have formed, by certain treatments, chloride and sulphide surfaces on iron specimens which they have then studied as to their behavior under extreme pressure conditions, and have found that the same behavior occurs as long as the surface lasts, as occurs with oils containing the e.p. additives. In other words, that further supports the theory, pretty well proven, that you have actually a chemical film of chloride or sulphide formed by the e.p. materials.

In answer to Mr. Cichelli's questions, the additive chemical groups of which we think may be quite a number of things. Of course, in the fatty oils they are pretty

well limited to one particular group, that is, the fatty acids which contain carboxyl groups. I can say that we do know that carboxyl groups, esters, and some inorganic radicals, including oil soluble sulphur, chlorine and phosphorous, are the types of materials that contribute to the chemical behavior or the surface active behavior of lubricants.

I am not sure that I understood the question about surface tension. Surface tension, or the manifestation of surface tension that has been used more widely in lubricating oil studies, interfacial tension, is a measure of certain behaviors of lubricants with respect to surface activity. We measure interfacial tension of oil against water more commonly than any other surface activity, or let us say surface tension behavior of oil. It is an indication of the concentration at the interface of materials which contribute to mutual solubility of oil and water. In other words, you have a strong interface. You have water and oil. Between those two, if you have no surface active compounds, you have no tendency to combine, no tendency to mix and emulsify. If you now add or develop through oxidation in the oil materials which are partly soluble in the water layers as well as in the oil layer, you get an effect which gives you that sort of thing. You have a greater tendency for some of the oil to go into the water. There will be molecules in the oil which are soluble at one end in the oil, and soluble at the other end in the water layer, and you have this mixing. If you go to the extreme and have greater solubility in water than in oil, you may carry some amounts of water into the oil.

If surface activity manifests itself a little further in affecting the forces of this interface so as to give a curvature between individual globules of water and oil, you may get a film of water surrounding a globule of oil, or you may get a film of oil surrounding a globule of water depending on the nature of the surface activations. When you get to that stage, you are getting emulsions, and that is the thing you have in the permanent type of emulsions, and in the extreme in the soluble oil type.

With respect to this problem on the change in lubrication requirements on changing from one type of journal to another, there are quite a number of factors that are different in the changed journal than in the original one. To begin with, you have changed the type of metal with which you are dealing. You have changed its composition to some degree, and you have changed its surface structure by a different composition first, and again by a different heat treating and finishing treatment. When you do that, you change the activity of oil toward that metal and you change, of course, the requirements in order to provide the wetability that is necessary.

As I understood it, you also changed clearances quite a little bit between bearing and journal, which again calls for some changes in the "wedging" effect of the oil. Results can be accomplished, of course, to some degree by changing viscosity. They can also be changed by differences in surface activity of the oil or through additives.

There is nothing seriously wrong with referring to e.p. materials in that respect as contaminants. Perhaps we are adding contaminants to the oil, which lessen the tendency of the metals to weld. We have through the action of e.p. material provided a surface which is not the original metal surface certainly, and in that respect we have something new which might be looked at as a contaminent. If you will guard against thinking of contaminants as undesirable materials, we have no objections certainly to calling these things contaminants.

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WILLIAM PENN HOTEL

PITTSBURGH, PENNSYLVANIA

SEPTEMBER 22, 23, 24 *and* 25, 1947

ELECTRIC RESISTANCE WELDED

Steel Tubing

. . . . there is no substitute for accuracy, or alertness in the manufacture of welded tubing . . . .

By E. W. ALLARDT

Chief Engineer, Welded Tube Division

Babcock and Wilcox Tube Company

Alliance, Ohio

▲ RESISTANCE welded steel tubing has been manufactured for about a half century. In spite of this length of time, progress is still being made in quality and cost reduction. It has had its share of the usual antagonisms as has other new products. Today the greatly accelerated use of welded tubing indicates that the stamp of approval has been given for its use in high pressure boilers for industry, railroads, and marine shipping. Its use in the many recently installed boilers attests to its high quality, its ductility, and perfect concentricity.

Resistance welded steel tubing is now made by the industry in sizes from ¼ to 26 inch diameters, all starting with flat strip or plate. By far the greater quantity of this tubing is in the low carbon range, SAE-1020. Some higher carbon tubing is welded such as SAE-1045, and also alloys similzr to SAE-4630. Some 0.100 carbon tubing has also been welded satisfactorily.

Alternating current is most commonly used with frequencies from 50 to 360 cycles, 60 cycle welders being the most common. As a result of the two heat peaks per cycle, and the consequent stitch effect that results from these heat peaks, the higher frequencies are gaining popularity, particularly where higher production speeds and higher quality tubing are required. A 60 cycle current welder operating at 90 fpm has a peak heat spot every 0.15 ($\frac{5}{33}$) inch. Obviously this does not produce as good tubing from the standpoint of weld perfection or strength, as does a welder operating at 180 or 360 cycles. The metal space between peak heat spots must be heated to welding temperature by conduction; consequently, it is necessary to provide greater current and heat values at the peaks to provide sufficient welding heat between peaks, which, in turn, may be the cause of electrode burns, or the formation of troublesome spatter ejected from the weld. Our No. 1 welder has been operating on 360 cycle current for four years producing the finest quality boiler and mechanical tubing, without any electrical difficulties of any kind. True, this welder has been almost completely rebuilt since its original purchase, but mostly to improve its mechanical characteristics to make it more suitable for continuous production. The original idea of concentric secondary current conductors has been retained.

One disadvantage of alternating current, from a mechanical standpoint, is the fact that at each alternation of the current, minute particles of iron, varying in size and quantity according to conditions in the welding throat, are exploded from the weld zone. These particles, which we call "spatter," sometimes cause difficulty when the inside weld bead must be removed by cutting or rolling. The success of inside bead cutting or rolling devices usually depends upon supporting rolls mounted on their underneath side. Such rolls will roll this spatter into the bottom of the tube, which is objectionable, and is cause for rejection.

Several welded tube manufacturers are today using direct current for welding to advantage. The advantage of direct current lies in its uniform heat producing effect which prevents the formation of troublesome spatter, and also permits almost unlimited speed. Someone might inquire about the comparative speeds of a-c and d-c tube welding, and I can give this comparison. We have produced very satisfactory 2 inch diameter tubing at 210 fpm on our No. 1 mill, 360 cycle welder, for a short run. I know of smaller size tubing having been welded satisfactorily with d-c at more than 400 fpm on an experimental run.

One disadvantage of d-c is its high first cost for the low voltage, high amperage generating equipment that is required. Such equipment, together with the necessary controls, costs about $1 per ampere for current so produced, as compared with $0.30 per ampere, or less, for alternating current equipment.

When designing and building our plant at Alliance,

Presented before AISE Pittsburgh District Section Meeting, February 10, 1947

Ohio, in 1942, we kept in mind the necessity of eliminating such variables that up to that time had interfered with high speed and continuous production of electric resistance welded steel tubing. The elimination of these variables will be described as this paper proceeds.

Figure 1 depicts a layout of the plant prior to recent minor changes necessary to still further increase production. The equipment throughout the plant is so arranged to cause as uniform product flow as possible, from incoming hot rolled mill edge strip to finished tubing. During the operation of our electric resistance welded tubing plant beginning January, 1943, approximately 120 million feet of carbon steel pressure and mechanical tubing have been produced.

Two electric weld mills are contained in the 665 by 100 ft main bay of the plant. No. 1 mill has a capacity of from ¾ to 2½ inch diameter, in gages from 0.049 to 0.134 in., and at speeds up to 200 fpm. No. 2 mill has a capacity of from 2 to 4 inch diameter in gages from 0.065 to 0.188 in., at speeds up to 120 fpm. Variable speed d-c motors on these mills, and throughout the plant, derive their current from a 400 kva ignitron tube rectifier. The two mills and their accessory equipment have a capacity of about 4000 tons of tubing per month, depending upon kinds and sizes made.

Hot rolled mill edge strip in coils, is used for about 95 per cent of the plant's production of tubing, and about 5 per cent of hot rolled pickled and oiled, or cold rolled strip, makes up the total. This hot rolled mill edge strip is rimmed steel, single rolled. Its use advantages lie in the fact that the lower carbon edges, that are not completely removed in the subsequent slitting operation, are somewhat easier to weld and also are not as susceptible to corrosion as is the core. Of the small percentage of cold rolled strip used, some of it is killed or semi-killed, multiple slit. The weld upset and subsequent trimming of this upset exposes the core of such strip to corrosive influences, and because the core is more susceptible to corrosion than is the rim, this type of steel is not used for boiler tubing.

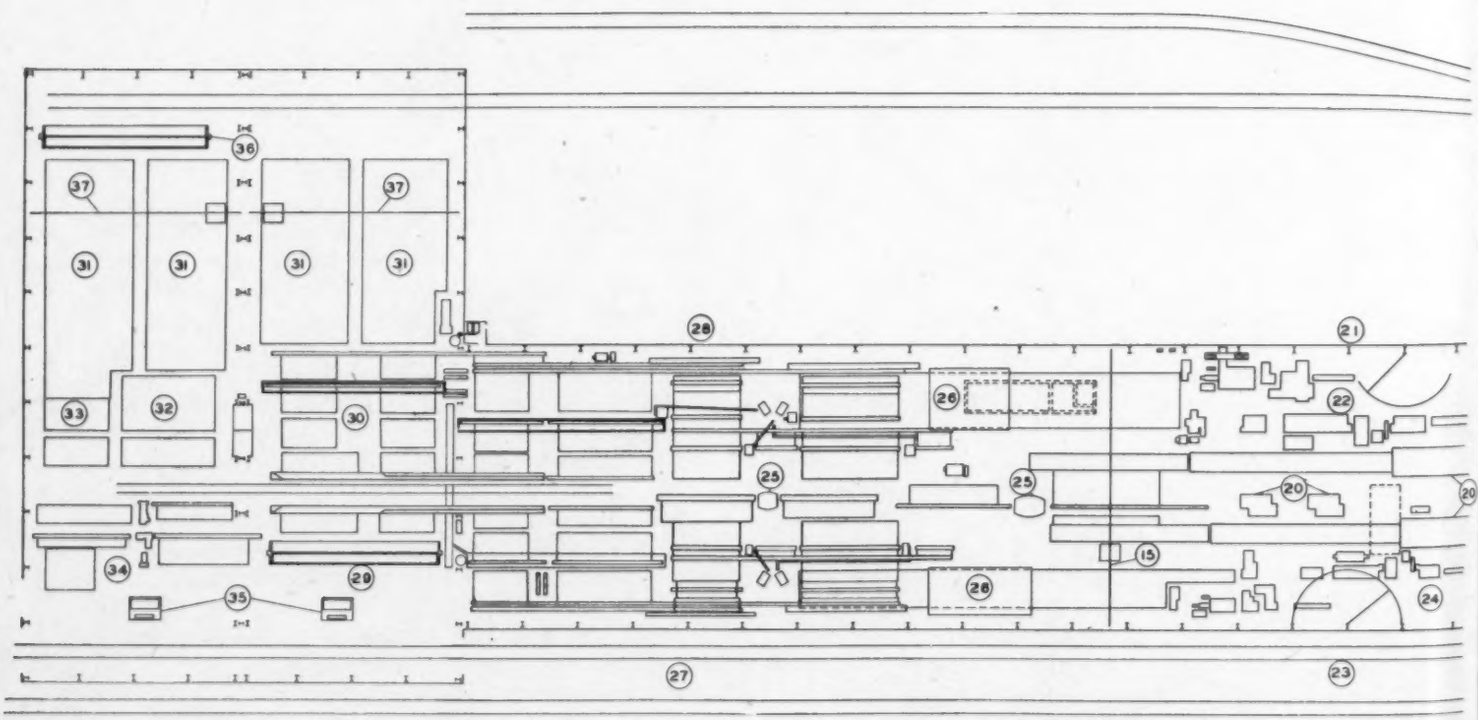
A storage space for approximately 5000 tons of hot rolled mill edge strip is provided. The coils are stored on edge in tiers three or more high, and are handled by crane hook of multiple length.

The control of our product starts with our laboratory analyzing samples of incoming hot rolled mill edge strip. Laboratory control continues after tubing is welded by testing samples for strength, and checking into such strip faults as laminations, split edges, insufficient rim at edges, or other defects that have been noted and reported during the welding operation. Photomicrographs of the weld on each heat of steel are made as a further check.

A boiler house extending beyond the main bay of the plant, contains two 284 horsepower boilers which supply steam for heating and agitating the pickle bath and rinse, and for miscellaneous heating. These boilers are coal fired with single rotary underfeed stokers. The ash is handled by conveyor system and is stored in a vitrified tile silo. The strip pickle house is an extension of the main bay and is parallel to the boiler house.

The first operation in the making of welded steel tubing at our plant is to run the hot rolled mill edge strip through a scale breaker. This breaker unit consists of a jib crane for handling coils from the adjacent storage space, a multiple coil box, feed rolls, scale breaking rolls, and recoiler with a coil discharge mechanism. The hot rolled mill edge strip is pulled through the convolu-

Figure 1 — Layout of the Babcock and Wilcox Tube Company's Welded Tube Division plant at Alliance, Ohio.

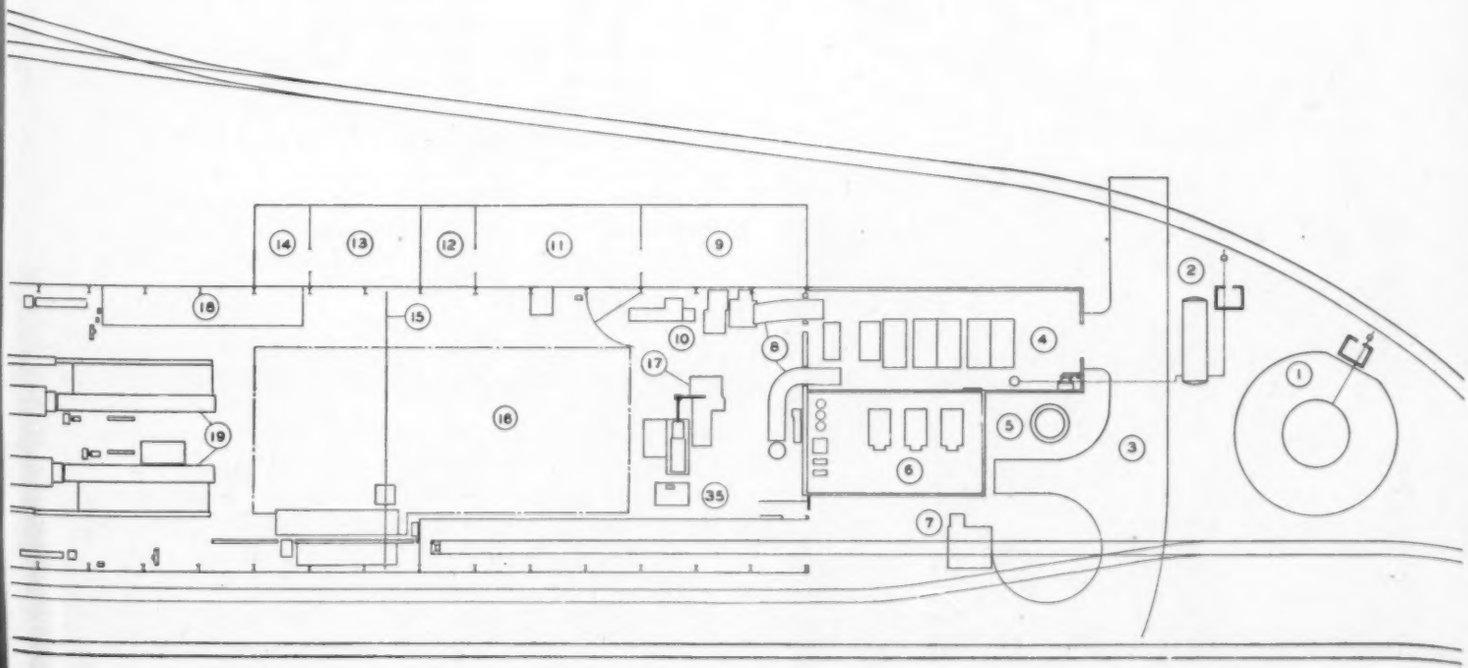


tions of the breaker rolls under tension by the recoiler. After the coil of hot rolled mill edge strip has been recoiled, it is back-spun by reversing the recoiler to open the individual wraps of the coil, and is then ejected from the recoiler into an up-ender which deposits the coil onto a short conveyor running into the pickle house. An electro-magnet mounted on a jib crane is used to move the coils from the conveyor onto acid-proof bronze racks for emersion in the pickle tubs. After the coils have been placed on these racks, the individual wraps of the coils are further separated with wire staples to prevent their contact while in the acid. Several layers of coils are stacked on the pickle rack depending on width of coil. The pickle solution is 6.8 per cent sulphuric acid by weight held at 165 F. An inhibitor and also a foaming agent are used to increase the efficiency of this operation. After pickling and hot rinsing, the staples are removed from the coils and the coils are then placed on a conveyor leading to the cold rolling mill.

At the end of the pickle house conveyor, coils of hot rolled mill edge strip are deposited onto a floor type uncoiling reel from which the strip is fed into a cold rolling mill. This cold rolling operation is the first control exercised to eliminate one of the variables that might easily interfere with the successful welding of tubing. This control eliminates contending with ordinary mill tolerances on strip thicknesses which in turn, permits closer heat control at the tube welder. Tubing with perfectly concentric walls is also the result of this operation. A reduction in strip thickness of 5 to 10 per cent is the average. A magnetic gage, running on the strip insures closer control of limits of thickness. Cold rolling is done in a mill with 16 inch diameter by 20 inch long rolls, at speeds depending upon the production requirements of the tube welding mills.

From the cold rolling mill, the coils of strip are trans-

(1) 75,000 Gal. Oil Storage Tank.
(2) Acid Storage Tank.
(3) Driveway.
(4) Pickle House.
(5) Smoke Stack.
(6) Boiler Room.
(7) Coal Hopper.
(8) Gravity Conveyors.
(9) Roll Grinding & Heat Treat.
(10) Scale Breaker Line.
(11) Machine Shop.
(12) Tool Room.
(13) Store Room.
(14) Electrical Store Room.
(15) 5 Ton Crane.
(16) Raw Coil Storage.
(17) Cold Roll Mill
(18) Switch Gear.
(19) No.1 & No.2 Mill Inlet Furnace Conveyors.
(20) No.1 & No.2 Mill Bright Anneal Furnaces & DX Units.
(21) No.2 Mill-Jib Crane, Coil Box, Uncoiler & Leveller, End Crop Shear, Butt Welder, Control Board, & Pinch Roll.
(22) No.2 Mill- Slitter & Scrap Chopper, Forming Mill, 500 KVA Welder, M.G. Set, Mill Drive, Sizing Mill & Cutoff.
(23) No.1 Mill- Jib Crane, Coil Box, Leveller, End Crop Shear, Butt Welder, Control Board & Pinch Roll.
(24) No.1 Mill- Slitter & Scrap Chopper, Forming Mill, 250 KVA Welder, M.G. Set, Mill Drive, Sizing Mill, & Cutoff.
(25) Straightener.
(26) Tube Storage Decks & Strip Loops.
(27) No.1 Mill, Finishing Dept.- Conveyors, Cutoffs, Elevators, Reamers, Testers & Inspection Racks.
(28) No.2 Mill, Finishing Dept.- Conveyors, Cutoffs, Elevators, Reamers, Testers, & Inspection Racks.
(29) Oil Dip Tank, Oil Drain Rack, Belt Conveyor, Buck Racks & Tester Sump.
(30) Tube Tester, Belt Conveyor, Inspection Racks, & Air Compressor.
(31) Tube Storage,
(32) Inspection Racks
(33) Salvage Racks
(34) Cox Cutoff, Cox Cutoff Extension, Oiling Racks, Straightener & Straightener Feed Table.
(35) Scales.
(36) Drain Rack & Tank.
(37) Shipping Dept.- 5 Ton Cranes



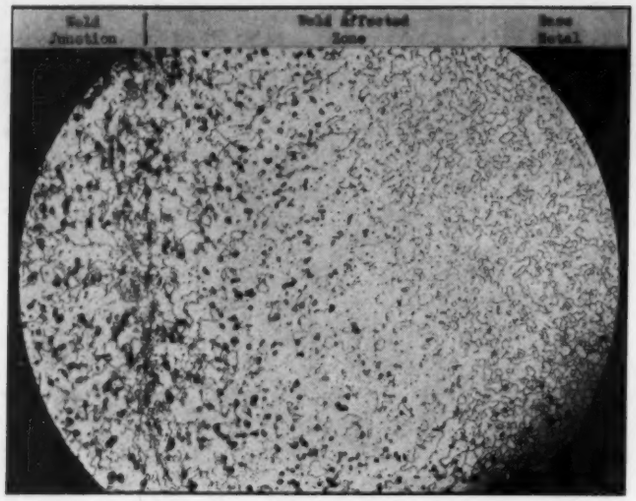


Figure 2 — Shown here is the structure of tube welded at normal current.

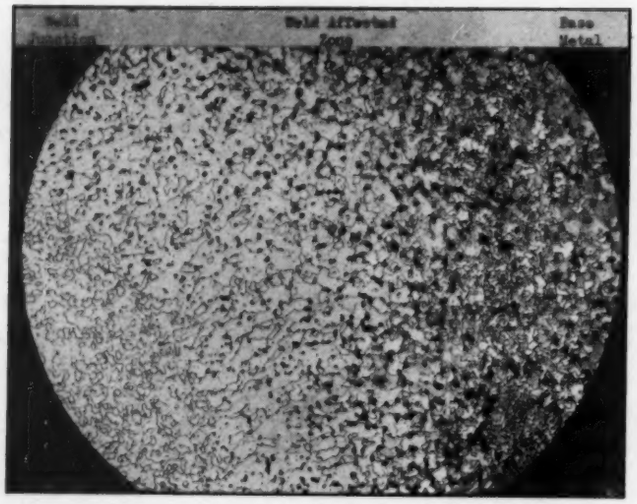
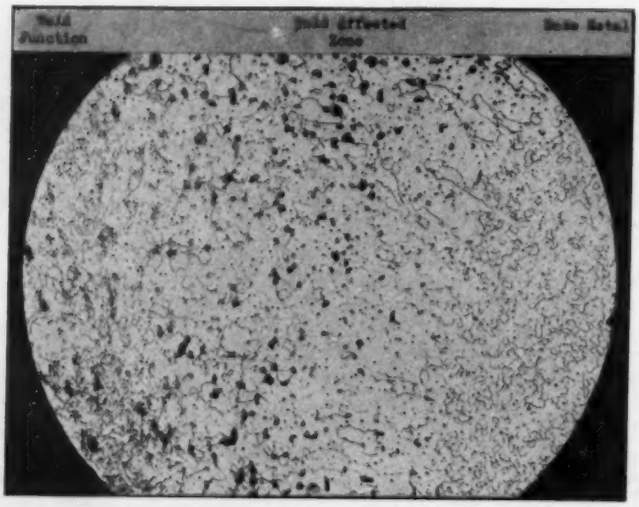


Figure 3 — Shown here is the structure of tube welded at 5 per cent excess current.

▲

Figure 4 — Micrograph of tube structure welded at ten per cent over current.



ported by crane on a multiple coil hook, to the storage space provided at each welding mill.

At No. 1 mill, the coils are lifted by a jib crane, as required, into a multiple coil box from which the strip is fed into a leveler. An upcut shear is provided after the leveler so that the ends of the coils may be cropped and cut square for the butt welding operation which follows. Coils of strip are butt welded together to form an endless strip to provide uninterrupted operation of the tube mill. The butt welder is provided with a hydraulically-operated draw shear to remove the welding flash. A pinch roll is provided after the flash shear, with controls interconnected with those of the leveler in order to permit running of the strip at a higher speed into a loop, prior to entering the tube mill. Running the strip into a loop permits the continuous operation of the weld mills while the butt welder and allied equipment operate intermittently.

The next operation in line of production is to slit the edges of the endless strip to the exact required width. Obviously, a minimum of selvage is trimmed off each side. This is another control introduced to provide strip of accurate and constant width. This eliminates another variable that we would be forced to contend with if commercial strip, with its commercial slitting tolerances, were used.

The slitting operation immediately before the forming operation also provides fresh edges to the strip, thereby eliminating the necessity of contending with rusty edges, or possible strip edge damage that might interfere with obtaining strong and sound welds. The natural slitting action also edge conditions the strip by imparting a slight bevel at the edges and at the same time causes a slight curvature to be formed at the underside surface edges. This curvature is in the direction of forming into tubular shape which follows slitting.

The slight thinning of the extreme edges as a result of the pressure between the slitting cutters is also a benefit in that less immediate heat is required at the convergence of the edges to effect a weld. The slitter is provided with such speed controls to permit its speed to be synchronized with that of the welding mill. Attached to this slitter is a chopper which cuts the slit selvage into short lengths for easy disposal into a tote box. While this slitting operation causes a loss of several per cent, in that the slit selvage is scrap, the advantage of having good edges to weld far outweighs this loss disadvantage.

Following the slitter is the tube forming mill which forms the flat strip into tubular shape preparatory to welding. The strip is progressively formed with rolls of high carbon, high chrome steel hardened to 62 Rockwell "C" and finish ground to close limits. Having our own roll designing, machining, heat treating, and grinding departments, has permitted us to furnish rolls to our mills to fit our high speed continuous operation. Many of our forming rolls have been provided with a hard chrome plate, from our own plating department, to provide a higher finish and greater life. This forming mill contains seven roll stands, not all of which are used for the smaller tube sizes.

That method of forming is best that produces the most uniform results, long roll life, shortest possible down time, and least possible distortion in formed tube.

A too abruptly formed tube can easily cause difficulty at the welder, for when heat is applied to highly stressed tubing edges, the resultant expansion may distort the product to cause intermittent burning, or to cause loss of control and subsequent rejection.

All forming, welding, and sizing rolls are carefully inspected after each run of tubing. Reconditioning to restore the original shape is done quickly when necessary, in time for the succeeding run of that size.

The formed tubing then passes into a 250 kva, 360 cycle resistance welder, spaced about 4 feet from forming mill. This spacing provides for flexibility of the possibly stressed tubing as a result of strip camber, and thus facilitates proper seam guiding by the seam guiding rolls which are mounted closely adjacent to the electrodes and welding rolls. These seam guiding rolls not only guide the seam to the exact center of the electrodes, but also control the tubing edges to prevent any variable movement of the point at which these edges converge. Beryllium copper electrodes contact the upper surfaces of the formed tube on either side of the seam.

Although these comparatively hard beryllium copper electrodes have lower conductivity, approximately 0.6 that of copper, we have not found it detrimental in any respect. We experienced no greater amount of burning, as one might have expected, nor did we notice any change in current values as a result of the higher resistivity. These electrodes being 85 to 90 Rockwell "B" maintain their shape better than ones previously used, and their ability to wear is approximately 30 per cent greater. We do not subscribe to the fallacy that electrodes should wear to the shape of the formed tube for proper contact, but rather should shape the tube with the assistance of the pressure rolls, to that shape that compels proper electrode and strip edge contact. These electrodes contain about 0.3 per cent beryllium, 1.5 per cent nickel, and the balance copper, and are heat treated to give the required hardness and toughness. One pair of electrodes recently removed from our No. 2 mill had produced 6,920,000 feet of 3 inch to 4 inch tubing. This unusually long life attests not only to the excellent electrode material but also to the stability of welder operation.

Pressure rolls, positioned on each side of the tubing directly beneath the electrodes, provide the pressure required to bring the edges of the tubing into contact, and to produce the required upset. Accurate gage and width of strip control, together with other accuracies built into the welder, permit such a precise combination of factors to compel as perfect welding as strip chemistry will permit.

The importance of accuracies in the welder roll and electrode assembly cannot be exaggerated. The geometry of the welding throat, which is that point near the center line of the welding rolls, and electrodes where the edges of the formed tube converge, together with the dimensions of the formed tube, must not be allowed to vary. We feel that variation in strip chemistry which is now beyond our control, is bothersome enough without having mechanical variations to interfere with producing an excellent weld. That shape of welding throat is best that compels trouble-free production, that provides proper and unvarying electrode contact without burning, and that also gives long life to the electrodes.

Our laboratories at Alliance and Beaver Falls, have

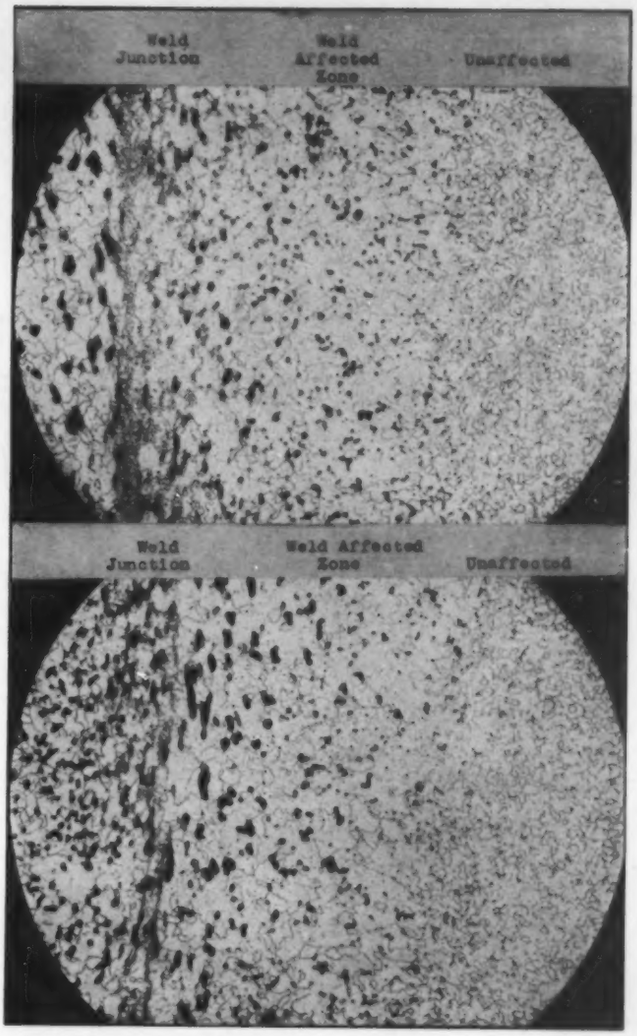
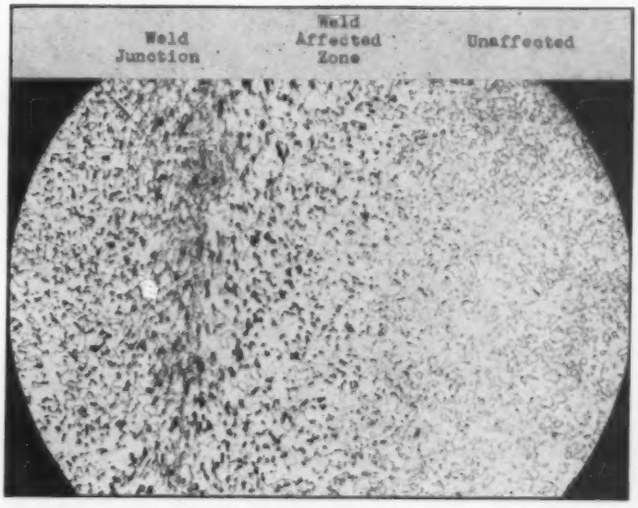


Figure 5 — On top is shown a weld made with normal current, and on bottom, tube was welded with current reduced five per cent.

▲

Figure 6 — This weld was made with the current reduced ten per cent.



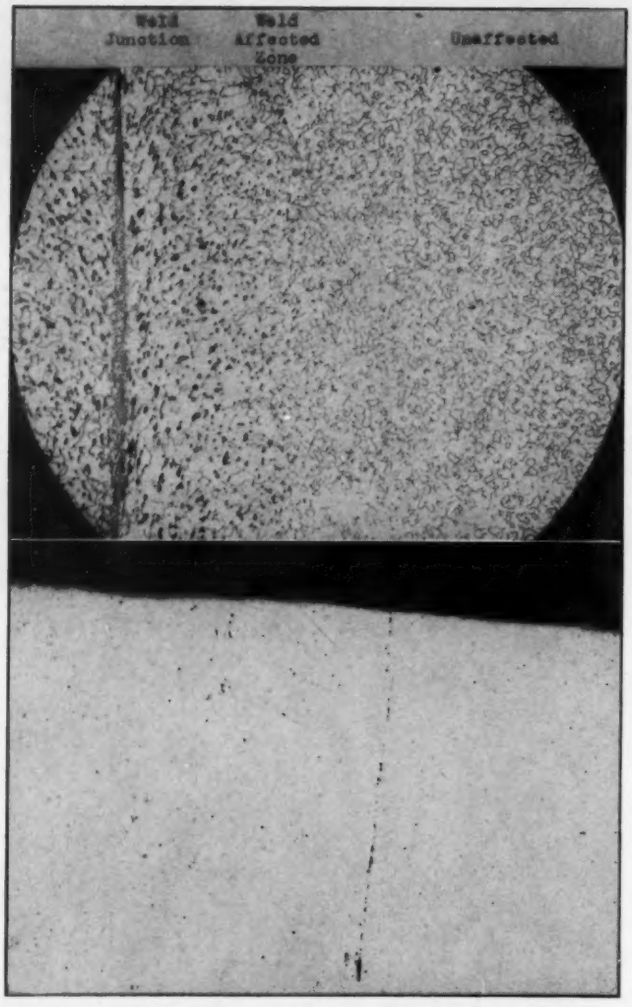


Figure 7 — This tube was welded with the current reduced 15 per cent. The top picture was made after etching, and the bottom picture, whose magnification is twice that of the bottom picture, is unetched and shows the void at weld junction outside surface.

determined after much research that welding heat variation of 10 per cent can mean the difference between a perfect weld and a poor one. Noting certain defects during destructive inspection of tubing early in our existence caused the investigation and consequent determination that welds made with heat 5 per cent above and below normal are satisfactory. Welds made with heat more than 5 per cent below normal are not satisfactory in that insufficient heat fails to cause complete fusion of the weld. It also causes the failure to exude extraneous matter, and oxide, from the joining surfaces. Welding current of more than 5 per cent above normal may cause excessive burn-in which is cause for rejection.

A quantitative indication of normal welding heat would be to use welding current that was just on the verge of producing burn-in. This norm is also determined by grain growth in the weld affected zone, that region between weld junction and base metal. The accumulation of such records indicates an average grain growth condition that serves as a criterion. Insufficient current and heat are disclosed by little or no grain growth, while excessive current shows up as excessive grain structure in the weld affected zone. All this assumes that welder components have been set up under identical conditions, made possible by accumulated standards.

It seems needless to say that such conditions are watched very closely, and not left solely to the judgment of the welder operator, so as not to permit the existence of subnormal or abnormal welding current.

One and one-half inch diameter by 0.134 wall boiler tubing produced at 99 feet per minute required 40,700 amperes, at 4.46 volts, to weld properly. The measured electrode contact of 0.25 square inches on each side of the seam, indicates a current density of 101,750 amperes per square inch. Every effort is made to control this electrode contact area so that the current density is not much more than 100,000 amperes per square inch. On the larger sizes of tubing, the electrodes are comparatively wider, and the wall thickness proportionally lighter than on the smaller sizes. Consequently, welding current values are comparatively less, indicated by electrode impressions which show a current density of approximately 50,000 ampers psi. Approximate electrode contact is determined by taking carbon paper impressions with very thin papers. Of course, such impressions must be taken on cold metal. It is assumed that electrode contact will vary but slightly under heat. Knowing the average amount of upset in the weld permits rather accurate determination of convergence point with relation to contact areas. Incidentally, this weld upset averages only $\frac{1}{32}$ inch of the total circumference on most all sizes of tubes, slightly less on small diameter light wall, and a bit more on larger and heavier tubes. If controls are lacking to permit this contact area to vary in size, or to permit the convergence point to fluctuate up and down stream of the electrode contact area, variations in current density may occur to vary the heat beyond such limits as will insure perfect welding. The whole purpose of the electrical circuit in the welder is to produce heat at the junction of the strip edges. If the right heat is produced at this point without producing enough heat to do harm anywhere else, the electrical circuit has performed its duty.

The factors, other than strip chemistry, making up the equation for a perfect weld are: uniform gage; uniform strip width; accurately formed tube; accurate control of the seam leading to the exact center of the electrodes; completely stable welding throat; stable welding current, and also the alertness of the welder operator to detect wear of such component parts as would change any one or more of these factors.

Variation in gage of strip causes variation in resistivity and consequently in the current and voltage values. Variation in strip width causes variation in formed shape and also shift of convergence point, consequently, variation in current density across the weld. Lack of seam control causes seam to shift sidewise which changes the resistivity of abutting edges and consequently the welding heat. This lack of control would also permit the movement of the convergence point up and down stream, changing current density across the strip edges. Eccentric runout and/or wobble of welding rolls and/or electrodes would cause variation in welding throat geometry, again causing variation in current and voltage.

Following the welding of the strip edges, tools are provided for cutting the outside and inside beads that are formed in the welding operation. The outside bead is wound on a friction clutch driven reel, and is disposed

of as required. The inside bead is disposed of by the flying rotary shear and conveyor attendant. This bead is then cut into short lengths by a chopper, for easy disposal.

A 5 per cent solution of soluble oil is used to provide lubricant for the forming, welding and sizing rolls, to cool the electrodes and also to cool the narrow line of heated metal immediately after welding.

A three pass sizing and straightening mill follows the resistance welder, to accurately size the tubing and to straighten it with reasonable accuracy. The welded tubing entering the sizing mill is sufficiently oversize so that the action of cold sizing will cause the tubing to retain its roundness and size. The welded tubing as it emerges from the sizing mill is cut to required length by a flying rotary cut off. This is a conventional machine containing air or hydraulically operated chucks to grip the tubing, and a rotating cutter head having three disc cutters which are pressed through the tubing walls while the machine carriage is in forward motion. The cut lengths of tubing proceed on and down a conveyor at the end of which they are discharged sidewise, into the bright annealing furnace.

A 75,000 gallon oil storage tank has been provided to store oil for firing the two bright annealing radiant tube furnaces during the winter months. Gas is used for firing during the summer months, or as long as gas is available. These furnaces, which are built with a 6 ft wide hearth, have a capacity exceeding 10 tons per hour. The atmosphere within the furnaces can be so changed as to provide an oxide finish to the tubing that is rust retardant.

On No. 2 mill, where the coils of strip are considerably heavier, a mechanical feeder is provided ahead of the leveler. Otherwise, the same sequence of operation is followed as on No. 1 mill; namely, leveling, end cropping, butt welding, flash shearing, feeding into a loop, slitting the edges, forming, welding, sizing and straightening, cutting to length, and conveying the tubing into a second bright annealing furnace. On this mill we have a 500 kva welder operating on 180 cycle current.

Tubing inspection starts with the inspector stationed at each mill; this might be considered the preliminary inspection. Here, the tubing is visually inspected for:

1. Burns, caused by improper contact between electrode and tube.
2. Lap, caused by edge of strip not being butted squarely.
3. Defective outside trim, caused by outside trimming tool being defective or not placed correctly.
4. Roll marks, caused by a portion of steel adhering to the roll and building up until it marks the strip as it passes through that set of rolls.
5. Electrode marks, caused by corners of the electrode being pushed into the metal leaving an imprint.
6. Inside scores, caused by inside trimmer being fouled.
7. Defective inside bead trim, caused by inside trimmer not set properly. This is inspected visually and by feel for over tolerance bead, undercut bead, or off-center trim.
8. Scores on outside surface, caused by the tube passing over some foreign objects.
9. Cutoff dents or marks, caused by cutoff jaws not being adjusted properly or by some foreign object being lodged in the jaws.
10. Any other defect that would appear to be injurious to the product.

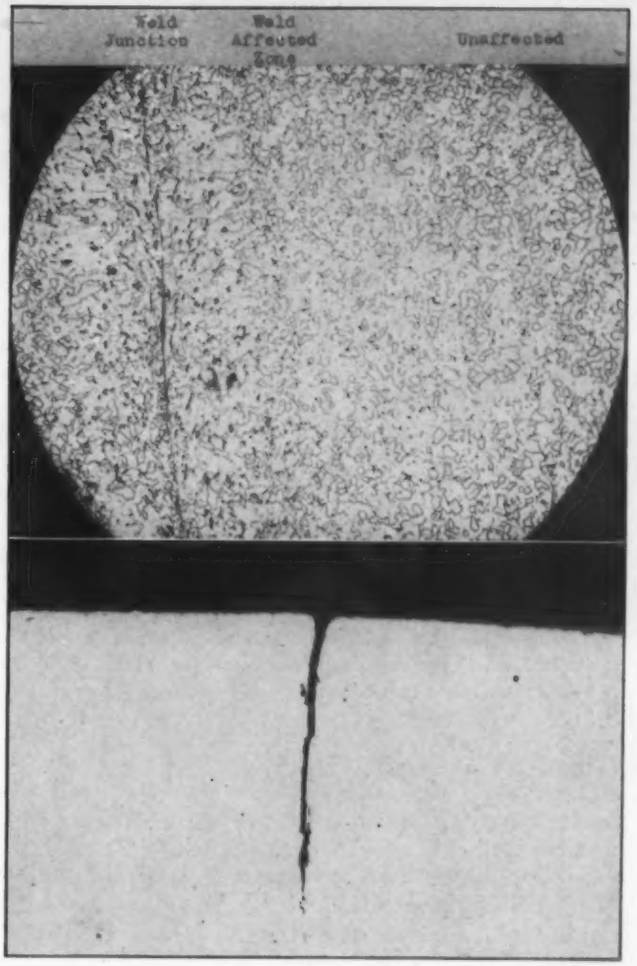


Figure 8 — These microphotographs are similar to those of Figure 7 except that the current was reduced 20 per cent. The harmful effect of the reduced current is illustrated in the lower photograph.

11. The length is measured at approximately ten minute intervals by removing a tube from the conveyor.

The inspector at the mill also conducts non-destructive tests by subjecting tubing to "Magnaflux" inspection. At this point, I would like to refer you to the article, "Quality Control During Production of Electric Resistance Welded Tubing," by Sidley O. Evans, which appeared in the *Welding Journal*, September, 1945. This article deals, "with the tests performed at the welders which are helping the welded tube division of the Babcock and Wilcox Tube Company to maintain weld quality so consistently that rejections, resulting from preliminary tests and hydrostatic testing of each length of pressure tubing, have averaged less than 0.3 per cent of the tubes tested month after month. The effectiveness of these tests depends not so much on the remarkable features of any one test as on the coordination of the group of tests to the characteristics of the mill.

"There is no better guarantee of a uniform, strong, complete weld in resistance welded tube than operation of the welding unit under such rigidly scrutinized control that it is never allowed to deviate from producing completely sound tubing. Constantly alert control is necessary even when the mill has been set up accurately and expertly, because wear and changes in strip

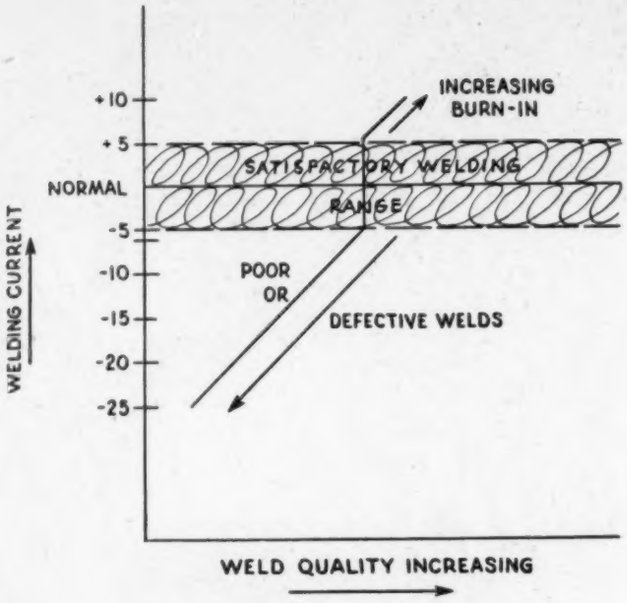


Figure 9 — The sketch shows the current range in which satisfactory welding can be done for 2.00 x 0.134 in. wall thickness tubes at a speed of 80 fpm.

characteristics may make adjustments necessary. Lacking this precise control, some tubing must be rejected as a sacrifice in the name of quality, but that sacrifice will injure rather than strengthen the confidence with which one may guarantee that the remaining tubing has a sound weld throughout its length.

"Production control that deserves confidence can only result from a combination of perfected tests and experienced men, frequent tests performed at the welding machine designed specifically to detect minor maladjustments on that mill, and men whose experience enables them to interpret the tests accurately and correct the maladjustments before serious defects have been produced.

"Magnaflux testing was chosen after an extensive investigation of the possible methods of non-destructive testing. Cold expanding of every foot of tubing was found to be prohibitively expensive. X-ray inspection was slow and the ability to see the minor defects was limited. Hydrostatic expansion was limited by mechanical considerations. All known methods of electromagnetic flaw detection were carefully investigated, and those which would apply to magnetic steel were tested on tubing having defects ranging from incomplete welds to actual leaks. These methods were rejected for two reasons: First, no satisfactory working compromise was found between a degree of sensitivity that gave unnecessary indications, and a lesser degree that sometimes missed defects even as serious as leaks. Second, the sensitivity was at the mercy of the operator.

"The Magnaflux test was adopted only after an extended period of development, during which it was studied carefully for limitations or blind spots and was adapted specifically for testing the weld area of electric resistance welded tubing."

The Magnaflux equipment, shown in Figure 10 consists of a type KQ-3 rectifier, 3000 ampere capacity.

A consolidated inspection report is rendered each morning listing types of rejections of the previous day's operations. Causes for such rejections are listed as leakers, burned welds, spot burns, lapped welds, light gage, defective inside bead trim, defective outside bead trim, scored inside, roll marks, defective ream or deburr, short tubes from cutoff, straightener marks, dinged tubes and crooked tubes. This report serves as a red-light warning to the succeeding days' operations, calling attention to necessary corrections or procedures.

Another daily report of interest is the delay report rendered by the mill operators, and operators of other groups of equipment. This report spotlights frequently occurring delays so that maintenance or engineering attention is given to correct quickly such deficiencies as are reported. This report also leads to the design of better equipment by pointing out physical weaknesses in the existing machinery, or improperly designed accessories from the production standpoint. For example, when we started weld mill operations, this delay sheet reported frequent interruptions due to having to change the outside bead trim tool. We designed a new trim tool that allowed us to perform this function without any delay whatever. Many other beneficial changes to original equipment, some simple, some radical, have resulted from the use of this delay report.

All pressure tubing is run through continuous atmosphere controlled normalizing furnaces operating at 1650 F to completely homogenize the structure to remove the difference in hardness produced in the weld. The two furnaces, one for each weld mill, are so located in the center of the plant that the welded tubing from each mill can be directly conveyed to furnace loading tables. The radiant heating tubes of the furnaces are arranged so that either natural gas or fuel oil can be burned. These furnaces will provide either a bright finish or a rust retardant oxide finish. The oxide finish is usually provided on tubing that is to be warehoused or otherwise stored prior to use. The top of Figure 11 depicts weld before normalizing, and the bottom depicts weld after normalizing.

Mr. H. F. Hinst, metallurgist of my company, has this to say about the problems affecting normalizing:

"The physical properties of the tubing are a result of those of the strip from which it is made, plus the effects of cold working during forming. The greatest change may be found in the lighter gages. The yield strength as measured by the offset method tends to approach the ultimate as in any case of cold working, but the elastic and proportional limits remain low. Directly paralleling any cold worked metal, recovery of the elastic limit may be produced by selective tempering treatments, and in some cases, tubing can be made to assume higher tensile values by the familiar age hardening process. The latter is confined to tubing made of rimmed steel due to the fact that killed steel does not exhibit this property.

"It is during the welding, cooling and bead removal operation that large stresses are concentrated in the weld area, being obvious by an increase in hardness in that particular zone. In commenting on this, it is of interest to note that the weld of an electric resistance welded tube is the strongest portion, and is higher in all physical properties save ductility in which it is always lower. In most cases, the ductility is still good enough to allow the tube to be flattened completely with the weld

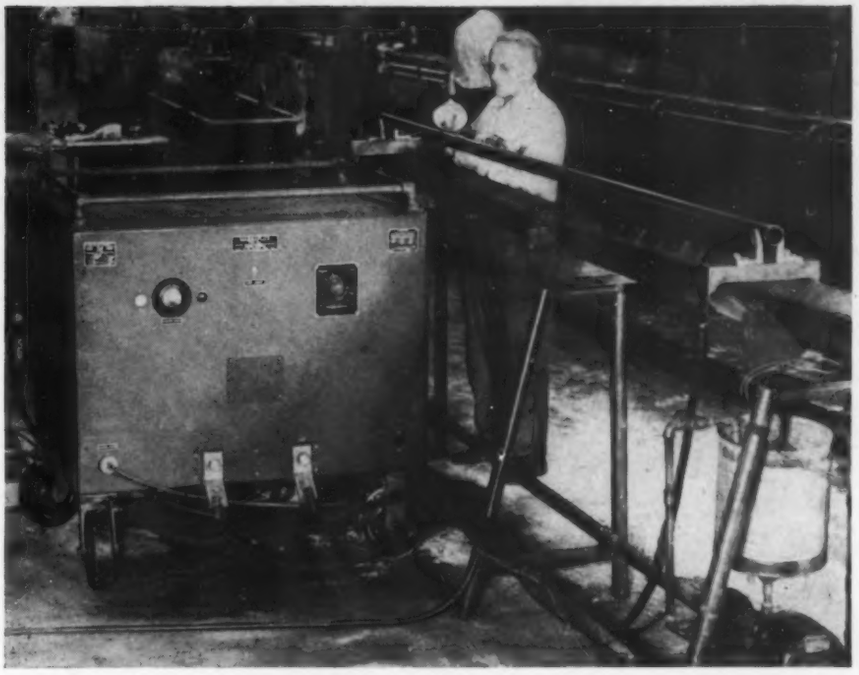


Figure 10 — Welded tubes are tested with magnaflux equipment.

in the line of maximum bend without any breaks in the surface becoming apparent. The presence of stringer sulphide or silicote inclusions in the weld area, detrimentally affects its ability to withstand deformation of this type.

"Normalizing the tubing at a temperature of 1650 F increases the ductility of the cold worked metal and weld area, drops the yield strength from its proximity with the ultimate, and renders the tubing more workable, which is of importance in beading, swaging, upsetting and expanding into headers.

"Sharp differences in stress concentration as between body metal and weld area metal invite corrosion by setting up a galvanic cell effect. Normalizing removes these abrupt differentials and minimizes this problem.

"The bainitic, sorbitic, and martensitic structures found at the weld after welding are completely transformed to a normal mixture of ferrite and pearlite, visibly identical with the rest of the steel at any magnification."

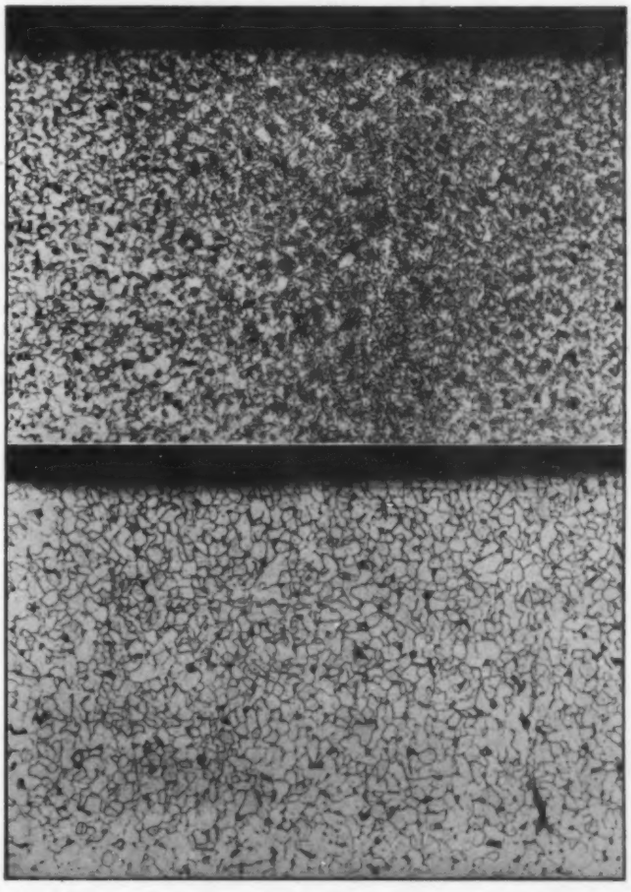
The cooled tubing emerging from the normalizing furnaces is discharged sidewise onto tables from which it is fed into rotary straighteners. After straightening, the tubing is conveyed to batteries of cutoff machines where it is cut to length as ordered.

Tubing discharged from the cutoff machines is then conveyed into double-end, semi-automatic de-burring machines, where the tube ends are chamfered inside and outside, and at the same time trimmed to exact length. Some orders require that tubing be reamed for 3 or 4 inches within each end; this is also done simultaneously with chamfering in these double-end machines.

Tubing discharged from the end de-burring and reaming machines is conveyed to hydrostatic testing machines, where the tubing is inspected for strength of weld as well as for possible leaks. We have several of these testers, in each mill line, to subject all pressure tubing to pressures from 1000 to 6000 psi, as required by specifications. In these testing machines, the high testing pressure is maintained for several seconds, timed by automatic timers, during which time the tubing is struck with mallets to vibrate it. Soluble oil, 5 per cent solution, is used as the fluid medium, because of its rust inhibiting qualities and its color.

Tubing discharged from the hydrostatic testers onto

Figure 11 — On top is shown a photomicrograph of the weld on a 3 x 0.109 in. tube before normalizing, and below is shown the weld after normalizing.



inspection skids is subjected to final inspection for the following possible defects: slivers; burns, spot and continuous; lapped edges; roll marks; conveyor marks; cable marks; cutoff marks; scores; wall thickness and bead height; diameter, use plug gage when specified; and inside surface defects. This inside surface inspection is accomplished by the helper holding an extension light on end of tube and inspector looking through opposite end. Both ends of the tubing are looked through in this manner, to make certain that the company symbol, heat code, welder code, and classification symbol are properly indicated.

After inspection, the tubing is conveyed into the transept building which is 160 feet by 220 feet, for final customer inspection and shipping. Frequently, purchasers of tubing, such as the Bureau of Shipping, the various railroads, and others, provide their own inspectors to pass final judgment on their tubing before shipment. Salvaging of such tubes as may have become work damaged enroute on the conveyor system is also done in this building. Those few tubes which inspection shows to have an inside weld bead height of more than our limit, are reworked in swaging machines to reduce this bead height to the desired limit. Tubes before shipping are dipped in one of several specified oils to resist rusting.

Fully equipped machine shops, hardening, grinding, and plating shops, have been provided for the complete manufacture of all tooling; such as, all rolls for forming, welding, sizing and straightening, and for miscellaneous accessories for other equipment as are required from time to time. Maintenance work is also done in these shops as required.

We at our company's welded tube division, have a peculiar and strong incentive to produce the best possible welded steel boiler tubes, for, no one could be more directly concerned with a boiler's performance than a boiler maker; a boiler is no stronger than its tubes, and we are an integral part of an organization that also builds boilers.

Throughout this paper, there has been the implication that there is no substitute for accuracy, or alertness in the manufacture of welded tubing. All one needs is well engineered equipment, plenty of "know how," and top management that inspires the best possible performance by the men who work the mills.

DISCUSSION

PRESENTED BY

N. C. RUBIN, Vice President, Yoder Company, Cleveland, Ohio

E. W. ALLARDT, Chief Engineer, Babcock and Wilcox Company, Alliance, Ohio

A. J. WAGNER, Superintendent, Tube Mill, Wheeling Steel Corporation, Wheeling, West Virginia

D. W. PATRICK, Plant Metallurgist, Jones and Laughlin Steel Corporation, Electricweld Tube Division, Oil City, Pennsylvania

F. W. BREMMER, Works Manager, Spang-Chalfant division of National Supply Company, Etna, Pennsylvania

E. J. REARDON, Vice President, Superior Steel Corporation, Carnegie, Pennsylvania

G. M. YOCOM, Assistant General Manager, Wheeling Steel Corporation, Benwood Works, Wheeling, West Virginia

H. M. WILSON, President, Taylor-Wilson Manufacturing Company, Youngstown, Ohio

R. A. CAMPBELL, Manager, Jones and Laughlin Steel Corporation, Electricweld Tube Division, Oil City, Pennsylvania

H. M. FEELY, JR., Chief Engineer, Pittsburgh Tube Company, Monaca, Pennsylvania

CARL H. HARTWIG, Industrial Salesman, West Virginia Power Company, Pittsburgh, Pennsylvania

A. T. RUTTENCUTTER, Industrial Salesman, West Penn Power Company, Pittsburgh, Pennsylvania

RUSSELL OGG, Weirton Steel Company, Weirton, West Virginia

N. C. Rubin: I have heard much from electric welded tubing manufacturers on the amount of electricity consumed. Is it any particular factor in your over-all cost picture?

E. W. Allardt: I would say no. On a 2 in. No. 10 gage boiler tube, the cost of current for welding only is about 3.1 cents per 100 ft of tubing, based on 1 cent per kwhr cost.

A. J. Wagner: The yield of which Mr. Allardt spoke seems very high. Is it really 99.8 per cent?

E. W. Allardt: No, it is not. I mentioned that our loss from "leaker" rejects had decreased to 0.03 per cent during this past year, and that in the last three months of 1946 was further decreased to 0.01 per cent, as a result of corrective actions taken following investigation using our method of "Magnaflux" testing. I might also mention that we have several other losses, some of which I mentioned in the paper. First of all, there is the scale break and the pickle loss, the crop end loss before butt welding, edge trim at the slitters, outside and inside bead trim, and another loss as a result of some open seam tubing made because of having to change an inside bead trimmer.

D. W. Patrick: There is one question I would like to ask. What were your results using multiple slit rimmed steel, keeping in mind that the rimmed edge would be very low carbon, and segregation could take place in the core? What luck have you had in making good welds?

E. W. Allardt: All of our boiler tubing is made with rimmed steel.

D. W. Patrick: Multiple slit?

E. W. Allardt: No, not multiple, it is single rolled. However, on mechanical tubing, the result of welding of core to rim has been exceptionally fine. I think that has been due to some extent to the close limits and the care we take at the welders.

F. W. Bremmer: I do not believe how much reduction which takes place in the cold rolling operation was mentioned, and I was wondering how much work they do there? Why is it that you use batch pickling rather

than continuous pickling; is it because this is a continuous weld layout?

E. W. Allardt: I believe I did mention in the paper that in our cold rolling process we reduce 5 to 10 per cent, and in some cases just a little bit more than that, depending upon our strip requirements at the mill at the time.

We do not use a continuous pickling process because of the economics. Our batch pickling is a less expensive installation in the first place, and does provide all of the capacity that we need for the operation of our mills.

E. J. Reardon: We are not in the tube business but we are in the strip business. I was somewhat surprised to learn that it was necessary to make this cold reduction. However, I assume the reduction was from hot rolled strip and the cold rolling process was necessary to obtain proper tolerances. I would like to have an indication as to the difference in tolerance from end to end in coil that is allowable in this process. In other words, how much of a tolerance do you allow from end to end in a coil for making welded tubes?

E. W. Allardt: We cold roll, or rather, cold size for several reasons. One reason is to produce the exact gage that we require. I believe I mentioned that we have a magnetic gage running on the strip on the discharge side of rolls, and time after time I have been out alongside the mill to see the strip varying plus or minus 0.001 in., no more than that.

I believe I can answer the question on variation in gage from one end of the coil to the other. Our records show that many coils do not vary in thickness from end to end, other coils show a variation of 0.004. Boiler tube specifications permit 0.008 variation from gage, but we make it a point to stay well within the maximum.

G. M. Yocom: I would like to ask about the steel that you multiple slit and weld; was it also rimmed steel, or did you say that was killed steel?

E. W. Allardt: We have run both rimmed and killed multiple slit, and it depended to some extent on what the mills could furnish us at the time. We find that our mills and our operators will handle either one just as satisfactorily. Such mechanical tubing as I mentioned is used for jack posts, conveyor rolls, and tubing of that sort.

H. M. Wilson: The speaker mentioned having test benches that test up to 6000 psi. Are there many specifications that require you to test that high?

E. W. Allardt: At the present time, no. During the war there were specifications in effect that required us to test up to those pressures. At the same time, we did test at higher pressures than specifications called for, just to make sure that we were doing a good job of welding.

R. A. Campbell: I understand that you have two mills, one using 180 cycle, the other one 360. Is there any appreciable difference in the uniform quality obtained from the two cycles? I am speaking again of mechanical tubing only.

E. W. Allardt: Yes, the 360 cycle mill is a smaller mill for smaller tubing, and because we have 360 cycle current, we feel that we can run at higher speeds and get better results than we can with 180 cycle current. On the larger sized tubing, such as 4 in. boiler tubing, the speeds are not as great, and 180 cycle current gives us the satisfactory result that we require.

R. A. Campbell: Is it a question of speeds then, between the cycles? Let us drop back then to 60 cycle compared to 360.

E. W. Allardt: To some extent, yes, as I mentioned in the paper, but the peak heat spots on 360 cycle welder are much closer than on 60 cycle, and of course the higher the cycle, the more the current approaches the effect of direct current, where there is no appearance of stitch effect at all, or it is so small it can hardly be detected. I would say that for smaller sizes of tubing, 360 cycle current is definitely superior, because I do not think there is any question at all but that it produces a better weld and consequently a better grade of tubing.

H. M. Feely, Jr.: Did you give any consideration to abrasive cleaning of the edges, on the hot rolled strip?

E. W. Allardt: Yes, we thought of all sorts of different ways, even carbide cutters running at extremely high speed. But the idea of abrasive wheel cleaning of strip edges was abandoned rather quickly, because of the impossibility of preventing wear of those wheels and consequent variation in strip width. And then too, unless the wheel were operated with a reciprocating motion, up and down across the strip, a round groove would wear very quickly in the wheel, which would impart a rounded edge to the strip, which we think is entirely unsatisfactory.

H. M. Feely, Jr.: What I had in mind was abrasive cleaning by using metallic shot.

E. W. Allardt: No, that was not considered, not just for cleaning the edges, because mill edge strip has a round edge, and we cannot use round edges in our welders. We did consider abrasive cleaning of the strip to replace pickling, but the dust problem was such that we rather quickly abandoned the idea.

H. M. Feely, Jr.: You mean the dust remaining on the steel, or the dust in the locality where the cleaning occurs?

E. W. Allardt: The dust in the locality of our mills.

Carl H. Hartwig: Is there any reason for not using an electronic means for annealing, for normalizing?

E. W. Allardt: Yes, there is the high cost at high speeds. We operate our mills in excess usually of 100 fpm and the cost of electronic annealing is so great that we had to abandon the idea.

Carl H. Hartwig: I noticed that The Ohio Seamless Tube Company of Shelby, Ohio, uses electronic means. I do not know what their production facilities are.

E. W. Allardt: That might be done if the speed of the weld mill were held down to maybe 30 fpm, or if one electric weld mill were used at high speed and three or four or five electronic heating means were then used. However, the cost is terrific. We had such an investigation conducted for us and we had to abandon the idea, only because of the high speed production and the high cost as a result of that.

A. T. Ruttencutter: I was interested in the point about blanketing your pickle tank to recover the acid. Does it also recover the heat losses?

The second question concerns the down time that occurs in changing the size of tubing. Do you run one production line continuously on more than one size,

or do you change the adjustment contacts of rollers, and consequently have down time?

E. W. Allardt: Do you mean when we change from one size of tubing to another, say from 2 to 4 in.? That requires a complete change of mill rolls, welder rolls, sizing rolls and so forth, and the time required is about five hours for the large mill, and somewhat less than that, say four hours, on the smaller mill.

On the pickle tank, we use a foaming agent that is simply used for the purpose of decreasing the spray effect and consequent acid loss as a result of the agitation of the pickle tanks.

A. T. Ruttencutter: Do you not get any insulation effect at all, while recovering the vapor loss at 165 F?

E. W. Allardt: Definitely it does blanket the tank to hold down heat losses to some extent, and we do save acid to the extent that less of the acid is carried away by the cross ventilation that we provide across the tanks.

Russell Ogg: You mentioned the sulphide inclusions in the welds as being detrimental. Would you venture to give any upper content of sulphur in the rimming steel, particularly that which is formed by multiple slitting?

E. W. Allardt: Sulphur content of 0.045 per cent is our specified top limit, but we have formed strip with as high as 0.072 per cent at the ends. This varies in an ingot, being higher in content at the top, and lower at the bottom, and also higher in the center than on the outside, so that a strip is likely to vary from one end to the other. Also, strips cut from the center of a wide sheet will contain more sulphur than those at the edges.

Tubing taken directly from the welding mill will exhibit the effect of sulphide inclusions by cracking along the weld upon flattening, the cracks being preferentially positioned there due to low ductility and high brittleness of the highly stressed weld area. Normalizing will completely restore the ductility of the weld area so that previously formed inclusions will have little or no effect on flattening of specimen.

D. W. Patrick: We have found on some samples of tubing that for the best quality weld, the parallel heat zone on either side of the edges is important. However, we have at times found some inverted "V" heat zones and some "V" heat zones where on the "V" heat zone, the flattening test will pass, but not the flange test, and for inverted "V" zones the flange tests pass but not the flattening test. What is the explanation for this?

E. W. Allardt: This condition is evidently the result of lack of control of seam edges. As a result of destructive tests, we also recognized this as a problem, so we quickly got busy and eliminated this condition by establishing dimensional controls so that we do not have so much of a variation of either inside or outside edge contact.

D. W. Patrick: That is where it all takes place, the extreme edge?

E. W. Allardt: Definitely.

KAISER STEEL COMPLETES TESTS ON EAGLE MOUNTAIN ORE

▲ THE Kaiser Steel blast furnace at Fontana, California has just successfully completed the first run on Eagle Mountain ore. These test results have exceeded the best hopes of the operators.

A small percentage of the ore was first put on the furnace on June 10 and the proportion was steadily increased until June 16, when 80 per cent of the burden was composed of Eagle Mountain ore, either as the raw ore or as sinter produced from the ore. This percentage was maintained until the completion of the test run on June 27, except for a two-day period when 100 per cent Eagle Mountain was charged. The total quantity of ore used amounts to 30,000 net tons.

Following are the significant figures for the test runs:

Period	June 16 to June 27	Entire run, June 10 to June 27
Eagle Mountain ore in burden, per cent	84.9	78.4
Scrap charged, lb/net ton	0	0
Average daily production, net ton	1,243	1,233
Average coke consumption, lb/net ton	1,437	1,451
Average flue dust production, lb/net ton	27	31
Average wind blown, cfm	60,000	60,000
Average coke ash, per cent	10.1	10.1
Average coke sulphur, per cent	0.98	0.99
Average blast temperature, F	1,163	1,173
Average blast pressure, psi	16.7	16.2

There were no changes made to the furnace, other than the change to Eagle Mountain ore. The furnace has a 25 ft-6 in. hearth diameter and was blown in on January 1, 1943.

The Eagle Mountain ore mined for the test was analyzed as follows:

Constituent	Natural analysis, per cent
Fe	53.91
Phos	0.031
Mn	0.05
SiO_2	8.21
Al_2O_3	2.45
CAO	1.69
MgO	3.15
S	0.293

The company believes that Eagle Mountain ore can be mined and delivered at Fontana at an Fe unit cost that is less than the corresponding cost for any other ore delivered at any other plant in the country. The company officials believe that this ore will be available for steady use in quantity sometime next spring. The amount of known ore in the deposit amounts to 25 million net tons, which should last for 40 years at the present rate of consumption. It is believed, however, that the amount of ore actually present in the area will exceed 70 years' supply.

1907 - 1947

TENTATIVE
PROGRAM

ANNUAL CONVENTION

ASSOCIATION OF IRON AND STEEL ENGINEERS

WILLIAM PENN HOTEL, PITTSBURGH, PENNSYLVANIA

SEPTEMBER 22, 23, 24, 25, 1947

TENTATIVE Program ... WILLIAM PENN HOTEL

17th FLOOR

Monday, September 22

9:00 a.m. — REGISTRATION — Silver Room

9:00 a.m.—LADIES' REGISTRATION—Parlors E and F

9:15 a.m. — BUSINESS MEETING — Urban Room
Conducted by President L. R. Milburn

9:30 a.m. — ELECTRICAL SESSION — Urban Room
Chairmen:
I. N. Tull
Republic Steel Corporation

H. L. Coe
Carnegie-Illinois Steel Corporation

"Twin Motor Drives for Tandem Cold Strip Mills," by R. H. Wright, Westinghouse Electric Corporation.

"Operation and Maintenance of Variable Voltage Control Systems," by A. D. Howry, Alan Wood Steel Company.

"Improved Reversing Mill D-C Generators," by C. Lynn, Westinghouse Electric Corporation and Walter H. Burr, Lukens Steel Company.

2:00 p.m. — ROLLING MILL SESSION — Urban Room
Chairmen:
A. G. Ericson
Carnegie-Illinois Steel Corporation

Louis Moses
Bethlehem Steel Company

"The Y-Mill — A New Type of Cold Strip Mill," by A. B. Montgomery and W. M. McConnell, Mackintosh-Hemphill Company.

"Factors in the Operation of a Mannesmann Piercing Mill," by H. R. McLaren, Timken Roller Bearing Company.

"Applications of the Basic Principle of Rolling in Roll Design," by Ross E. Beynon, Carnegie-Illinois Steel Corporation.

2:00 p.m. — OPERATING PRACTICE SESSION — Cardinal Room

Chairmen:
J. H. Vohr
Carnegie-Illinois Steel Corporation

R. P. Tooke
American Rolling Mill Company

"Job Evaluation," by L. H. Brown, Wheeling Steel Corporation.

"New Technique in Conditioning Stainless Steel," by A. E. Hamilton, Jr., Hamilton Pump Company, Inc.

"The Powder Process in Stainless Steel Production," by C. J. Burch and E. M. Holub, The Linde Air Products Company.

Tuesday, September 23

9:00 a.m. — COMBUSTION SESSION — Cardinal Room

Chairmen:
C. J. Wyrough
Jones and Laughlin Steel Corporation

C. E. Duffy
Bethlehem Steel Company

"Uses of Oxygen in Steel Production," by J. H. Zimmerman, The Linde Air Products Company.

"Oxygen in the Open Hearth," by E. C. McDonald, Republic Steel Corporation.

"Agitation of the Open Hearth Bath with Oxygen and Compressed Air," by J. N. Hornak, Carnegie-Illinois Steel Corporation.

9:00 a.m. — STANDARDIZATION SESSION — Urban Room

Chairmen:
F. W. Cramer
Carnegie-Illinois Steel Corporation

V. E. Schlossberg
Inland Steel Company

Standardization Committee Report — F. W. Cramer, Chairman, AISE Standardization Committee.

Final Report of D-C Mill Motor Committee.

Reports on Operational Experience with New D-C Mill Motor.

Effect of Proposed New AISE Mill Motors on Motor Brake Design.

Report of Committee on Standardization of Safety Switches.

Report of Committee on Standards for Surface Finish.

2:00 p.m. — COMBUSTION SESSION — Cardinal Room

Chairmen:
C. W. Bruce
Republic Steel Corporation

B. B. Bargman
Carnegie-Illinois Steel Corporation

"Oxygen and the Steel Industry," by Harry W. McQuaid and F. E. Pavlis, Air Products, Inc.

"Steam Generation and Maintenance of Power Stations for Steel Plants," by John J. Alexander, Republic Steel Corporation.

"Auxiliary Fuels in Gas Fired Steam Units," by A. R. Mumford, Combustion Engineering Company, Inc.

2:00 p.m. — ELECTRICAL SESSION — Urban Room

Chairmen:
M. B. Antrim, Lukens Steel Company
D. C. Nelson, Jones and Laughlin Steel Corporation

"Electric Heating of Steel Strip for Continuous Processing," by A. R. Ryan and F. E. Ackley, General Electric Company.

"Trends in Lifting Magnet Design and Application," by John D. Leitch, The Electric Controller and Manufacturing Company.

"Glass Fiber Electrical Insulating Materials," by Harry O. Collis, Owens-Corning Fiberglas Corporation.

Wednesday, September 24

9:00 a.m. — INSPECTION TRIP — New Facilities at Homestead Works, Carnegie-Illinois Steel Corporation

2:00 p.m. — LUBRICATION SESSION — Cardinal Room

Chairmen:
C. R. Hand, Bethlehem Steel Company
D. N. Evans, Inland Steel Company

"Industrial Uses of Synthetic Lubricants," by W. H. Millett, Carbide and Carbon Chemicals Corporation.

"Rolling Lubricants for Cold Mills," by R. J. Nekervis and R. M. Evans, Battelle Memorial Institute.

"Barium Lubricating Grease," by C. J. Boner, Battenfeld Grease and Oil Corporation.

2:00 p.m. — STANDARDIZATION SESSION — Urban Room

Chairmen:
F. W. Cramer, Carnegie-Illinois Steel Corporation
E. L. Anderson, Bethlehem Steel Company

"Proposed New Crane Specifications," by I. E. Madsen, Association of Iron and Steel Engineers.

"Report on Crane Bridge Drive Specifications," by Marc de Ferranti, General Electric Company.

"Research Report on Design of Crane Ladle Hooks," by Professor C. W. Muhlenbruch, Carnegie Institute of Technology.

"Research Report on Design of Hot Metal Ladles," by K. Knudsen, W. Munse and B. Johnston, Fritz Engineering Laboratory, Lehigh University.

Report of AISE Sling and Crane Chains Standards Committee.

7:30 p.m. — Formal Dinner-Dance — Ball Room

Speaker: C. R. Cox, President, Carnegie-Illinois Steel Corporation.

Thursday, September 25

9:00 a.m. — MECHANICAL SESSION — Urban Room

Chairmen:
H. W. Neblett, Inland Steel Company
T. R. Moxley, Wheeling Steel Corporation

"Metals in Service," by P. M. Hess, Safe Harbor Water Power Corporation.

"Principles of Job Scheduling in a Machine Shop," by L. E. Fuller, Jr., Carnegie-Illinois Steel Corporation.

"Effects of Shot Peening and Cold Rolling on the Characteristics of Steel," by O. J. Horger, Timken Roller Bearing Company.

9:00 a.m. — OPERATING PRACTICE SESSION — Cardinal Room

Chairmen:
C. P. Betz, Hanna Furnace Division, Great Lakes Steel Corporation
J. L. Tatman, Wheeling Steel Corporation

"Preparation of Coal for Coke Production," by Preston E. Jordan, Wheeling Steel Corporation.

"Coke Oven Machinery," by Ragnar Berg, Koppers Company, Inc.

"Progress of High Top Pressure Operation of the Pig Iron Blast Furnaces," by B. S. Old, E. L. Pepper and E. R. Poor, Arthur D. Little Company.

2:00 p.m. — LUBRICATION SESSION — Cardinal Room

Chairmen:
C. E. Pritchard, Republic Steel Corporation
R. S. Shoemaker, American Rolling Mill Company

"Lubrication of Rolling Mills," by L. E. Lovitt, Socony-Vacuum Oil Company.

"Some Aspects of Lubrication Equipment Maintenance," by Robert A. Kraus, Republic Steel Corporation.

"An Improved Method for Mounting Bearings and Couplings," by A. Stewart Murray, SKF Industries, Inc.

2:00 p.m. — COMBUSTION SESSION — Urban Room

Chairmen:
H. S. Hall, Lukens Steel Company
C. M. Yaeger, Jones and Laughlin Steel Corporation

"Soaking Pits at Middletown American Rolling Mill Company," by H. V. Flagg, American Rolling Mill Company.

"Multiple Fuel Burners for Open Hearth Furnaces," by J. M. Brashear, Inland Steel Company.

"Design and Performance of an Air Recuperator," by E. G. Smith, Amsler Morton Corporation.

An Invitation to Steel Mill Operators and Engineers

Forty years ago the capacity of the U. S. iron and steel industry was 38,000,000 net tons. Today it is 2½ times as large — 91,241,230 net tons. This growth has gone hand in hand with the growth of the Association of Iron and Steel Engineers which was founded forty years ago. We believe we are justified in claiming a share of this increase in capacity as well as an increase in the efficiency of operation. The advancement of the technical and engineering phases of the production and processing of iron and steel has been the consistent purpose of the AISE. Through the medium of meetings such as the AISE annual convention, we have exchanged ideas to our mutual benefit.

The officers, directors and staff of the Association have given careful thought to the program for the fortieth year. Each engineering division is represented on the convention program with selected authors and subjects. We firmly believe that you cannot fail to take home from this convention many good ideas that you can use in your plant to the advantage of both your company and yourself.

As has been our custom during the past forty years, we extend a cordial invitation to all operators and engineers of the iron and steel industry to meet and join with us in the interchange of our ideas for the advancement of the industry.

L. R. MILBURN

President, AISE

Heating and Rolling

LOW CARBON STEEL FOR STRIP

. . . . in the production of hot rolled strip steel, close and active cooperation is necessary between the mill operator and metallurgist if quality and production are to be attained . . .

By N. E. ROTHENTHALER

Superintendent of Production Control

Steel Division

Ford Motor Company

Dearborn, Michigan

▲ ABOUT seven thousand years ago mankind passed from the Stone Age to the Age of Metals. Through the following historical eras progressive use was made of bronze and iron, principally for weapons. In 672 B.C. the Hittites, a tribe in Asia Minor, overthrew the Egyptian rule in Syria. These Hittites were armed with iron swords. This is the first historical reference to the use of iron.

The effect of heat on metals was known early in the Bronze Age when alloys of copper and tin, hand forged while hot into sharp weapons, became hard upon cooling. No doubt in the transition from the use of bronze to iron, advantage was taken of the increase of malleability of iron when heated. And so through the ages iron was hot forged into various shapes and sizes.

It is only during the past fifty years that development of the steel industry has made such great advancements, culminating in our present modern steel mills. To describe each phase of this development is beyond the scope of this paper. However, it is the purpose of this report to describe the modern technique employed to properly heat and roll steel from ingots into slabs, and from slabs into coiled strip. As each of these individual operations could be reported in great length, the latter will be stressed and only the basic principles of the former operation will be reviewed.

Even as the ancients employed the use of heat to soften their iron for shaping, so do we continue to do. Based upon the study and practical knowledge of the behavior of the various steels, we have instituted metallurgical controls to produce quality steels for innumerable applications. These controls have been made automatic wherever possible by modern instrumentation.

It is within our present memory that all sheets were produced on the so-called two-high mills, hot rolled to the final gage. Several of these old mills are still in operation, rolling principally high silicon electrical sheets. The conversion of the sheet steel industry from the now obsolete hand mills to the continuous wide strip mills during the past twenty years required an entirely new technique of operating and metallurgical controls.

Temperature control was used primarily for proper rolling properties, whereas today temperature control plays an important part in the final physical and metallurgical properties of the hot rolled strip steel. Whereas the old hot rolled sheet was not usable in its finished rolled state without subsequent annealing, the hot rolled sheet or strip produced today is applied directly to the fabrication of difficult formed parts.

Beginning with the ingot charged into the soaking pit where we find the first reheating operation, specified temperature ranges have been instituted for proper rolling of the reheated ingots. For low carbon steels which are destined for sheets, a range of 2350-2400 F is specified. This temperature can only be measured superficially with manually operated optical pyrometers.

The ingot must be thoroughly soaked at this temperature to ensure sound slabs during rolling on the blooming mill. The quality of this heating operation depends a great deal upon the judgment of the soaking pit heater who supervises the various stages of heating and soaking of these ingots. To relieve the heater from the manual manipulation of the firing of these pits, automatic controls are installed to regulate the firing of the pit, as shown in Figure 1.

The heater can then devote his time to closer observation of this operation. Direct flame impingement on the ingot surface will cause localized burnt areas which

Presented before AISE Detroit District Section Meeting, January 14, 1947

Figure 1 — Automatic controls relieve the heater of manually controlling the pits.

are hot short and will tear and crumble upon rolling. This must be prevented to reduce the hazard of increased scrap and reconditioning costs. Rimmed steel ingots with blowholes close to the surface must be heated with great care to prevent over-oxidation of this surface, which may expose these gas pockets to the atmosphere and thereby become oxidized. This condition would prevent the satisfactory welding of these gas pockets during rolling and form, instead, slivers and scabs detrimental to a quality surface. These so-called "thin-skinned" ingots occur mostly in the higher carbon rimmed steels.

There are various types of soaking pits throughout the industry. Each type has its own particular operating features. At the Ford Motor Company we have installed recuperator type pits with opposed burners located near the bottom and with automatic heating controls which are now satisfactorily in operation.

The ingot as it is discharged from the pits must have a uniform scaled surface without any indication of "washing" or overheating.

The initial rolling on the blooming mill must be made with care, without excessive drafts to prevent any surface rupture. The ingot is turned from side to side on the first few passes to condition it from a casting into a state capable of being forged. On some of the very tender alloy steels the blooming mill operation was made in two steps with intermediate reheating. This was done to convert the ingot from its cast condition to a forging state, without too drastic conditioning in the blooming mill.

At the Ford Motor Company three ingot sizes have been standardized for rolling into slabs: 22 × 36 in., 22 × 44 in., and 22 × 55 in. This size range permits us to produce slabs varying in widths from 24 to 51 in.

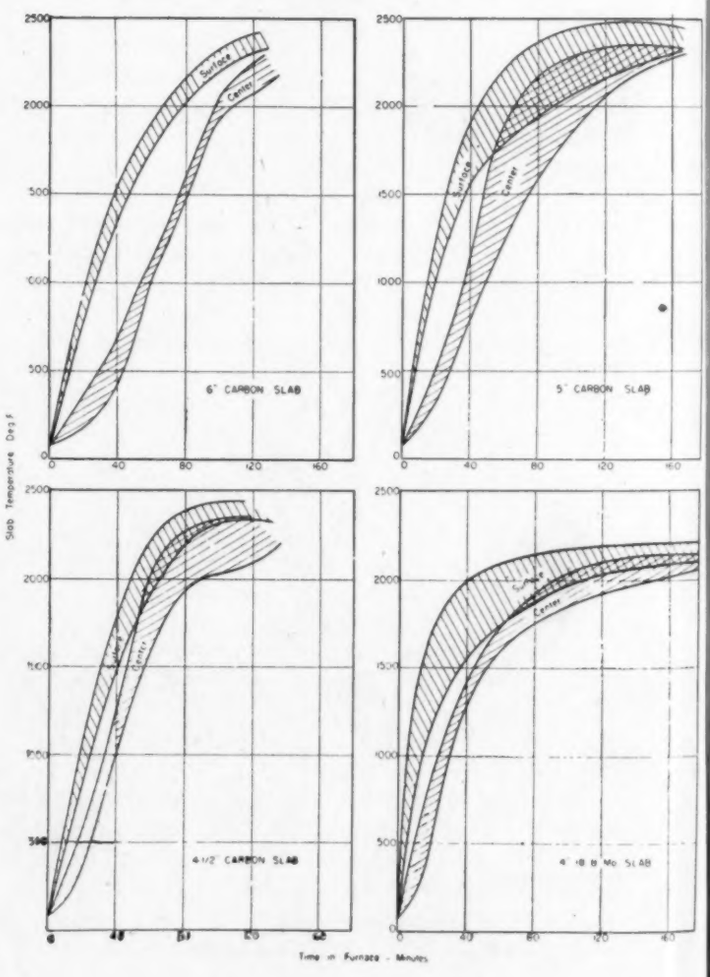
These ingots are reduced on the blooming mill to thicknesses ranging from 4 to 5½ in. and to a predetermined width as governed by the ingot size. Thin-rimmed ingots are treated with additional passes to prevent surface ruptures from drastic drafts. The ingot must be reduced a minimum of four inches on its edge to obtain a properly edged slab.

The temperature of each ingot in the blooming mill is automatically recorded with an automatic optical pyrometer. This instrument records the temperature at each pass. It is a silent arbitrator between the blooming mill rollers and the soaking pit heaters, for it registers irrefutable evidence of whether the ingot is at the proper temperature.

The ingot emerges from the blooming mill in the form of one long slab with irregular ends. The slabbing shear removes these ends, and shears this bloom into the desired slabs. Approximately 85 per cent yield is obtained from each ingot. This yield permits the croppage of the piped and segregated ingot top and the overlapped bottom ends.

The majority of the blooms are sheared into two slabs. The length is governed by the spread of the skid rails and width of the slab reheating furnace. The maximum and minimum slab lengths in these long sizes are from 192 to 154 in. However, those slabs which are

Figure 2 — Envelope curves of surface and center temperature of slabs during heating.



scheduled for broadside rolling are sheared four to a bloom with a maximum length of 79 in. and a constant width of 45 in. The thickness of the slab is adjusted on the blooming mill in cooperation with the slab shearing so as to obtain a maximum yield of 85 per cent to fit the minimum and maximum lengths. The shear operator must remove all visible pipe.

The hot slabs leaving the shears are transported to the slab yard where they are permitted to reach a normal temperature. They are then spread upon the conditioning beds for inspection and scarfing. The surface defects as marked by the inspector are removed by a scarfing torch. Such defects as cracks, tears, slivers, scabs, rolled-in slag, crumbled edges rolled-in scale, and seams must be removed by the scarfer. This operation is an important one for final surface quality. Although earnest effort has been made in the preceding operation to prevent the occurrence of these surface defects, they are not 100 per cent controllable. However, the percentage of occurrence is maintained at a minimum. Slabs scheduled for re-rolling into cold rolled sheets are given greater inspection, while those for hot rolled sheets are also inspected, but slight defects which are harmless to the product, or which will be scaled off in re-heating, are disregarded.

Each slab is identified with a heat number and its location from the ingot. This location is maintained to permit the application of top cuts into shallow drawn parts, while bottom cuts are scheduled for the very difficult parts. However, as the slab width has already been established, the flexibility of diverting top cuts is restricted. Consequently only a few deep drawn parts can be accommodated by this diversion.

The slabs are now ready for charging into the three-zone continuous recuperative reheating furnaces where they are brought to the proper temperature for final hot rolling. Due to the restricted area at the time of the construction of these furnaces, four furnaces forty-five feet in length were installed. These units can be oil or gas fired or a mixture of both. The temperature of these furnaces is maintained at 2400 F. With proper maintenance, three furnaces are kept in constant operation. The fourth furnace is operated whenever possible to permit maximum production on the hot strip mill. The heating capacity of a single furnace is 35 tons per hour. A four-ton slab is heated in 90 minutes and is discharged every 7 minutes. The soaking hearth length is 8 feet. Based upon the above heating rate, this permits 16 minutes for soaking time.

The general construction of this type of furnace in other mills is similar except that the length is increased to 80 feet or more with longer soaking hearths.

The inside dimension of the furnace from wall to wall is two hundred and three inches, which permits a maximum slab length of 192 in., allowing for expansion. The water-cooled skid rails are set approximately 40 in. apart. With four rails per furnace we can roll two short slabs end to end or one long slab.

Direct firing of the furnace is controlled by the heater to maintain the maximum temperature. The force of the flame is kept from direct contact with the slabs to prevent localized overheating.

Optical pyrometer readings have been made on the heated slabs, but due to the influence of flame, smoke, and scale conditions in the furnace, these readings have not been reliable.

At the annual AISE convention in 1946, J. W. Percy of the United States Steel Corporation, presented a paper on the "Heating Rate Tests on Slab Reheating Furnaces," which was published in the July, 1947, *Iron and Steel Engineer*. He presented some very interesting data on the slab temperature measurements, which are of interest. These temperatures were obtained with a specially designed thermocouple which was inserted in previously drilled holes in the slabs to measure the internal slab temperature at the various furnace ports. Another pyrometer was constructed to measure the slab surface temperature.

These temperatures as measured by Mr. Percy record the variation from the surface to the center of the slab. It is significant to note the equalization of temperatures during the soaking period where the surface temperature is reduced until the slab is at a uniform temperature. See Figures 2 and 3.

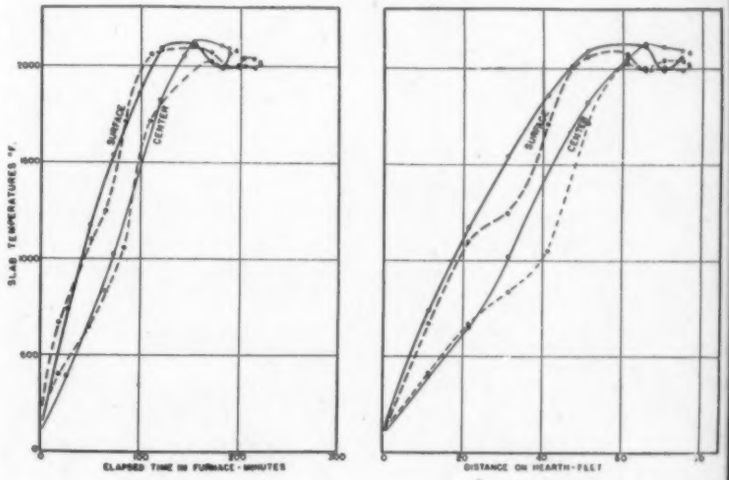
These curves illustrate the typical heating cycle in the slab reheating furnace. As mentioned previously, we have a hearth of only 45 feet; consequently, our over-all heating time is proportionately faster.

The operation of the slab reheating furnace is controlled by automatic draft regulation with constant supervision by the heaters. They must regulate the burners to produce a uniform thoroughly heated slab for proper rolling quality. Constant observation of internal furnace condition is necessary to avoid overheating at this high temperature. A running or dripping scale condition indicates excessive localized heating which must be prevented.

The roof condition of the furnace is carefully checked in order to determine when relining is necessary. The spalling of these bricks deposits brick fragments on the slab which tend to fuse. These fragments must be scraped from the slab surface before it enters the mill or it will form a long reddish streak embedded in the surface, which will cause rejections at the finish end.

The movement of the slabs through the furnace is also constantly watched to avoid jams. As these slabs are pushed from the charging end, any factor disturbing the forward movement of these slabs will cause them

Figure 3 — Surface and center temperatures of 7⅛ x 30 x 11 in. slab going through reheating furnace.



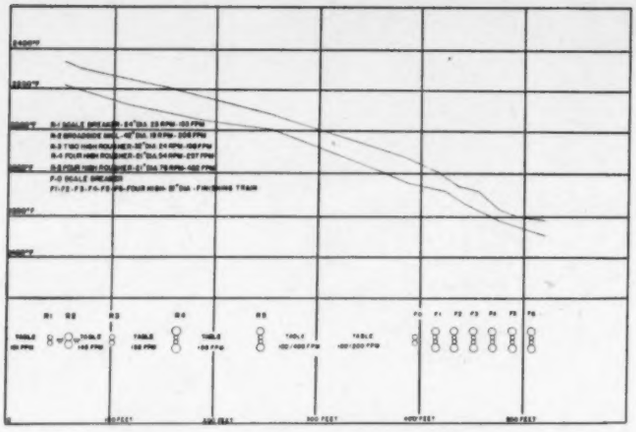


Figure 4 — The chart shows the maximum and minimum temperatures of the strip as it goes through the mill.

to shift sideways and jam against the furnace walls. Too short slabs may be pushed off the skid rails and block the furnace. Another typical poor operating condition is for one slab to overlap another.

The slab is discharged directly on the roller table conveying it to the first stand in the hot strip mill. This mill is composed of one 56 in. 2-high scale breaker, one 96 in. broadside mill with auxiliary turn-tables, one 2-high 66 in. roughing stand, and two four-high 66 in. roughing stands with auxiliary edging rolls. The finishing train contains one 66 in. 2-high scale breaker, and six 4-high 66 in. finishing stands.

The slab temperature entering the first stand in the roughing train is approximately 2350 F. At the exit of the fifth stand, which is the second four-high roughing stand, an automatic temperature recorder is located. This instrument is used principally as a check against the slab heating furnace. The temperature registered at this point of rolling is between 1950 and 2000 F. This reading is closely observed by the roughing mill roller for uniformity from slab to slab. The roll conveyor table connecting the roughing train with the finishing train is 150 feet long. Installed on this table are air cooling jets which are used primarily to raise the scale, which permits better surface finish and also reduces the strip temperature to the desired final finishing temperature as measured after the last stand in the finishing train.

Although it is preferred that the final temperature be taken between the fifth and sixth finishing stand, too much spray and smoke obscure this area for an accurate reading. The final pass is only a light draft for surface finish and final gage control. It is the draft on the fifth finishing stand, however, that influences the grain structure in the hot strip, especially in the critical gages.

A composite temperature curve has been made illustrating the maximum and minimum temperatures observed through the entire hot strip mill. The temperature range was averaged from a series of temperature records, Figure 4, on hot strip ranging from 14 gage

Figure 5 — Recording pyrometer chart of hot rolled strip after the last roughing stand with temperature gradient of over 100 F due to cooling effect of the water-cooled skid rails.

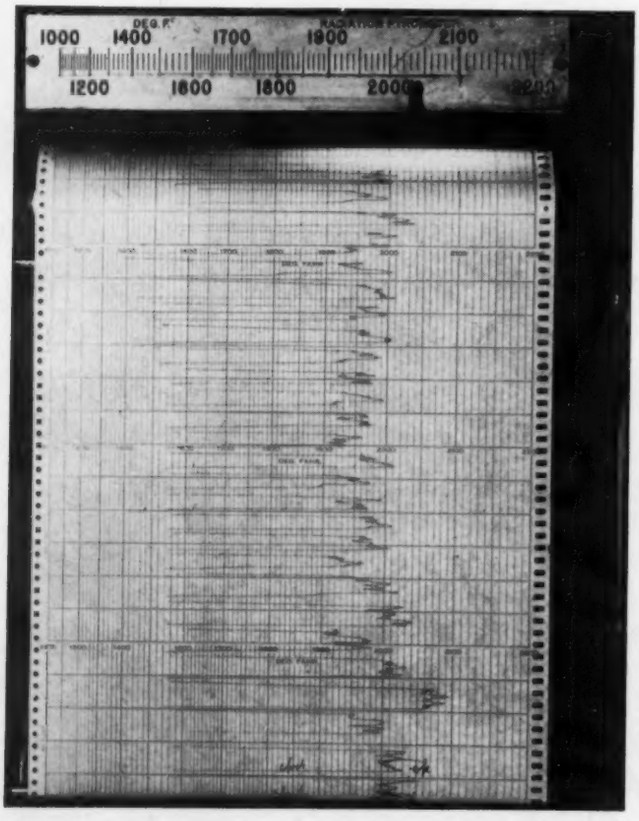
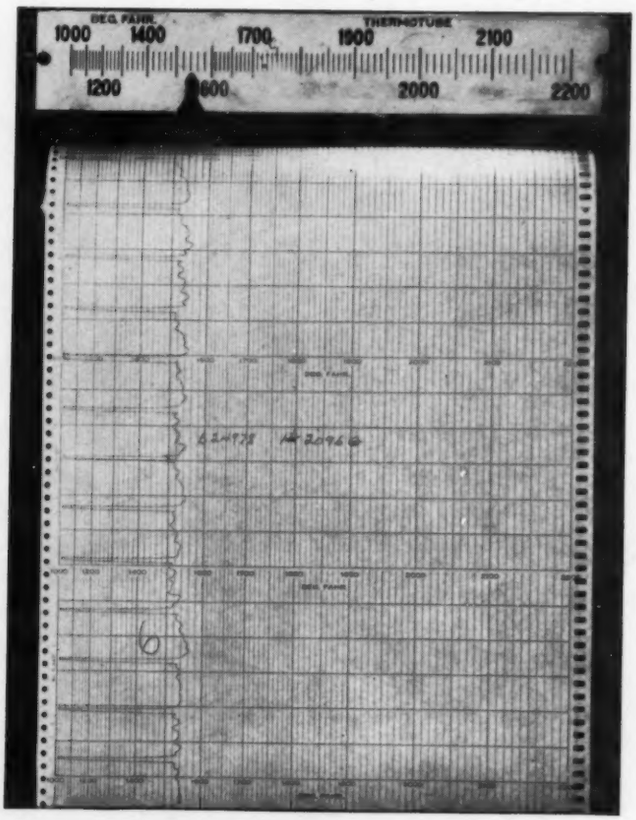
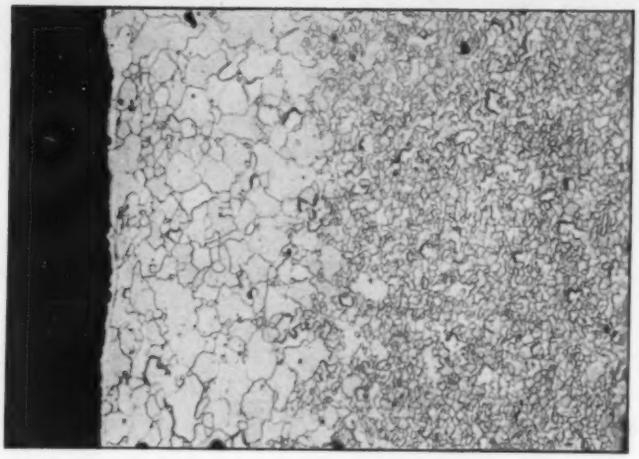


Figure 6 — Chart shows temperature of strip after last finishing stand. Skid rails have cooling effect of about 30 F.





Laboratory number	1051
Low Carbon Heat	1681E
Hot rolled 14 gage	0.081 in.
Tensile strength	50,400 psi
Yield point	40,200 psi
Elongation in 2 in.	47 per cent
Elongation in 8 in.	28 per cent
Brinell hardness	90
Carbon	0.065 per cent
Manganese	0.31 per cent

Figure 7 — Microstructure of 14 gage (0.081 in.) hot rolled strip, finish rolled below the critical temperature of 1600 F.

(0.084 in.) to 11 gage (0.125 in.) which is the principal gage range as rolled on the Ford hot strip mill.

Regardless of all the effort made to produce a uniformly heated and soaked slab, the influence of the water-cooled skid rails is predominant throughout the entire hot rolling process. The automatic temperature recorders sharply indicate the drop in temperature in that area of the hot strip which has contacted these skids. A definite drop of as much as thirty degrees can be observed on these charts, as shown in Figures 5 and 6.

Ordinarily if the gage is above 0.095 in. with the finishing temperature in the fifth finishing stand above the critical temperature of 1600 F, no metallurgical effect is noticed. However, on the lighter gages where the finishing temperature is at or below the critical temperature of 1600 F, the steel will show a coarse irregular surface structure in the microscope.

The grain coarsening effect is produced by straining the steel below its critical temperature, and allowing the ferrite grains to re-crystallize and grow during the subsequent slow cooling period in the coil. This metallurgical effect is influenced by three variables, the amount of strain, the temperature of the steel, and the carbon content.

Figure 7 illustrates this coarsened structure. According to Sauveur this grain coarsening phenomenon is exhibited only by the low carbon steels up to 15 points of carbon.

Were this steel quenched immediately after working in this temperature range, a uniform grain would result. If, however, any additional reheating below the critical temperature was made upon this quenched steel, a coarse grain structure would be formed. Consequently, to avoid this granulation, attempt is made to roll above the critical temperature if possible or to cool the strip as rapidly as possible with water sprays.

All the hot strip rolled on the Ford hot strip mill is hot coiled. The strip reaches the coilers at approximately 1300 F. Superficial surface cooling is made with water sprays to control the grain structure as mentioned above. Also, these sprays partially control the final physical properties of the steel, depending upon the chemistry and the gage.

Water sprays help also in the following continuous pickling operation by making the scale more friable.

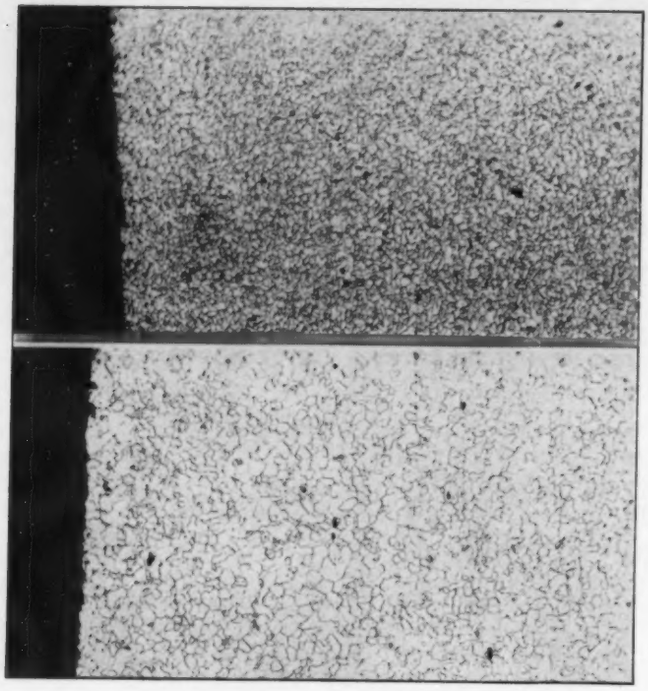
Each mill order on the hot strip mill is set up by the metallurgical department for final finishing temperatures and water sprays. The hot rolled strip destined for hot rolled products must be metallurgically satisfactory to form these parts without further heat treatment. Consequently, the final structure and hardness must be controlled by these specifications.

Fortunately in the production of hot rolled steel at the Ford Motor Company, close observation can be made in the application of these steels on the job. Any rolling condition which is affecting its performance can be corrected without too much loss of time. Figure 8 shows a difficult part made direct from hot rolled steel which has an excellent performance record of low scrap percentage.

Hardness tests made on the hot rolled steel from 18 gage to 14 gage range from 58 to 62 on the Rockwell B scale, and consequently cannot be used for deep drawing parts without further heat treatment. In order to reduce this Rockwell 10 points or more, annealing is required. If subcritical annealing is employed, a maximum temperature of 1250 F must be used. Higher temperatures will cause grain coarsening and subsequent granulation during forming as described in the previous paragraphs.

In rolling hot rolled strip for later cold rolling into fenders and other deep drawn cold rolled parts, a mini-

Figure 8 — This frame cross member, 0.187 in. thick, 0.08 per cent carbon, 0.35 per cent manganese, was formed from as-rolled hot strip steel.



Laboratory No.	2620
Aluminum killed	Heat 4468G
29A-16015	
Hot rolled	0.103 in.
Brinell hardness	107
Yield point	47,200-45,700 psi
Tensile strength	59,000-58,750 psi
Elongation in 8 in.	25-24 per cent
C	0.07 per cent
Mn	0.35 per cent
P	0.007 per cent
S	0.031 per cent
Cr	0.02 per cent

Laboratory Number	1770 (No. 11)
Silex Heat	
9N-16,616	
Hot rolled	0.118 in.
Brinell hardness	95
Yield point	37,400 psi
Tensile strength	49,500 psi
Elongation in 8 in.	29 per cent
C	0.065 per cent
Mn	0.36 per cent
P	0.006 per cent
S	0.023 per cent

Figure 9 — On top is shown typical structure of hot rolled aluminum killed steel, and on bottom is shown uniform hot rolled structure of low carbon steel finish rolled above 1600 F.

mum hot rolled gage of 0.107 in. will prevent coarse surface grains with a good degree of safety. In the early days of the continuous wide strip mills great contention was encountered among the various metallurgists whether the coarse surface grains affected the final cold rolled structure. From our experience the influence of coarse grain structure exists in the final cold rolled steel unless the steel is normalized above 1700 F.

Figure 9 illustrates this uniform equi-axial ferrite grain structure on hot strip steel rolled above 1600 F.

This coarse grain phenomenon was prevalent in all the hot rolled sheets produced on the old two-high hand mills where the final finishing temperature was well below the critical temperature.

The box annealed sheet at that time showed large irregular-shaped ferrite grains. These sheets were applied only on shallow formed parts.

The deep drawing sheets were normalized to relieve the working strains and then box annealed for greater ductility.

In the production of the hot rolled strip steel, close and active cooperation has been maintained between the mill operators and the metallurgical department. These quality and production minded groups have made a successful team for the production of this steel. Each of these groups has had an important share in the development and operation of the continuous wide strip mills of today.

DISCUSSION

PRESENTED BY

P. E. HAGLUND, Melting Superintendent, Ford Motor Company, Dearborn, Michigan

JOHN C. DUDDY, Superintendent, Hot and Cold Mills, Ford Motor Company, Dearborn, Michigan

N. E. ROTHENTHALER, Superintendent of Production Control, Steel Division, Ford Motor Company, Dearborn, Michigan

E. L. PATTEN, Electrical Engineer, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan

J. A. SHIMMIN, Superintendent of Maintenance, Rotary Electric Steel Company, Detroit, Michigan

C. E. S. EDDIE, Assistant Superintendent, Steam and Fuel, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan

J. L. HOTT, Superintendent, Steam and Fuel Department, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan

H. F. LESSO, Open Hearth Control and Materials Metallurgist, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan

H. E. EMIGH, George W. Hofmann Associates, Detroit, Michigan

P. E. Haglund: Is there any difference in rolling a low and a high carbon steel in the hot strip mill in regard to speeds? Can higher speeds be used on a low carbon than on high carbon steels?

John C. Duddy: That all depends upon what the laboratory requires. The hot strip temperature is controlled principally by the speed of the mill. If lower temperatures are required, the mill speed is reduced.

Member: Do you now find in your experiments, or in your experience, that better control on a hot mill decreases the need for box annealing?

N. E. Rothenthaler: The Ford Motor Company

has no facilities for annealing hot rolled strip, consequently all our hot rolled strip must make a satisfactory product. Of course, there are some cases where coarse surface grains occur, which cannot be applied directly on deep drawn parts. For example, oil pan stock, 16 gage, hot rolled, from this mill would not form satisfactorily because it would granulate in the deep draw, and break at the corners. We get a satisfactory product on limited applications when we metallurgically control the rolling of the hot strip steel.

E. L. Patten: Would there be any advantage in retaining the heat in the slab, by hot scarfing rather than cold scarfing as it leaves the blooming mill?

N. E. Rothenthaler: There would certainly be considerable advantage in the heat effect in the heating cycle in the furnace. It would mean that you could speed up your furnace. If, instead of charging a cold slab into the furnace, the hot slab is charged from a hot scarfer into the furnace, you would save all that temperature and get the advantage of the retained heat. I believe some of the mills are following this practice. In the past we have charged some hot slabs from the blooming mill directly into the furnaces. However, the steel was scheduled for hot rolled parts, and the surface was satisfactory.

J. A. Shimmin: Did the difference in the temperature you noted, caused by the skid rails, influence the final surface or physical properties in any way?

N. E. Rothenthaler: If the gage were marginal, approximately 0.085 in., and the temperature of the strip were at 1600 F the temperature at the skid rail contact area would be below the critical temperature of 1600 F, and a coarse surface structure would result in this area.

C. E. S. Eddie: I would like to know if you attempted to insulate the sides and bottom of water cooled skid rails in your reheating furnace.

N. E. Rothenthaler: The water cooled skid rails are set on the top of brick piers throughout the length of the furnace, and fire clay is used to cement the sides of the rails to this pier. This installation insulates the bottom and sides of the water cooled skid.

J. L. Hott: What is the relation of soaking zone to heating zone?

N. E. Rothenthaler: The total over-all length of the furnace hearth is 45 ft, of which 8 ft is the soaking hearth at the discharge end. We can get only two slabs, 48 in. wide, on the soaking hearth at one time. The length of our hearth is limited due to the space available at the time of the construction of these furnaces.

H. F. Lesso: In view of the differences in the plastic flow characteristics of steel with increasing carbon content, if you have previous knowledge that the product being rolled is thin skinned, do you modify your mill speed to reduce the tendency to surface rupture?

N. E. Rothenthaler: We do not do so much in the mill speed, but handle the drafts on that steel, so as not to open up or give too much excessive draft to open up the thin surface skin. Speed is relatively the same, but the draft is cut down considerably, and the ingot is given more careful handling through the mill, and additional passes are made.

H. F. Lesso: I suppose you do modify your percentage of reduction through the finishing stands?

N. E. Rothenthaler: After it reaches the strip mill, no modification is made. We do not find any ruptures occurring in the strip mill. In converting the cast ingot into a slab, that is, changing it from a casting into a forging, it is necessary to heat and roll this steel carefully. After the ingot is once rolled into a slab without rupturing the surface, it can be treated as an ordinary slab.

H. F. Lesso: Of course, you do remove a certain percentage of the surface even on thin skinned slab in your reheating furnace?

N. E. Rothenthaler: Yes. Care is necessary in the heating of thin skinned ingots not to over-scale and expose the blow holes.

H. E. Emigh: What is your definition for spheroidize annealing? I heard a lot of arguments on that for years from metallurgists, during the war.

N. E. Rothenthaler: Actually, spheroidizing is the conversion of the carbides into spherical or globular shapes as a result of a long-cycle annealing at the lower critical point, Ac_1, or slightly below it.

H. E. Emigh: Are the spheroids fully dispersed or what?

N. E. Rothenthaler: The spheroidization and dispersion depend principally on the annealing cycle.

H. E. Emigh: Would you say 85 per cent?

N. E. Rothenthaler: Yes. It depends upon the annealing cycle; I have seen them as low as 10 per cent.

H. E. Emigh: We found out in processing and rolling heats for extra deep drawn jobs on ammunition, such as cartridge cases, that 85 per cent spheroidize annealing made a good drawn job, meeting all ordnance ballistics requirements.

N. E. Rothenthaler: That is right. A long time cycle is necessary to bring it into that state. I can recall an instance in the early part of the war when brass was very critical, and steel was being tried for cartridge cases. We were all called down to Washington, and there was a lot of hesitation on the part of the steel companies to produce that type of steel.

H. F. Lesso: In your paper you made reference to a critical dimension. Will you enlarge upon that please, with reference to various types of steel and particularly increasing carbon content?

N. E. Rothenthaler: Yes. That was principally a reference to the granulated surface. On our mill set-up, below 0.090 in. gage through the mill is critical as far as the surface structure is concerned. In other words, we don't hold temperatures above 1600 F on 0.090 in. or less.

H. F. Lesso: What carbon range?

N. E. Rothenthaler: The carbon range was below 15 points. Above 0.15 per cent carbon this phenomenon does not occur. Sauveur has a very good chapter on grain growth, showing the sub-critical annealing of strained low-carbon steel. It illustrates the effect of temperature and time on the grain growth which occurs during the various stages of the annealing of strained steel specimens.

H. F. Lesso: I suppose you do not have that critical problem in the real high carbon thin skinned materials.

N. E. Rothenthaler: No, it doesn't exist above 0.15 per cent carbon.

J. A. Shimmin: Did you say that you introduced

a blast of air some place in the furnace to create a scale condition?

N. E. Rothenthaler: I mentioned a cooling table. We have air jets located above the roll conveyor between the roughing and finishing trains, extending approximately half the length of the conveyor. These air jets were installed for two reasons. One reason was to reduce the rough strip temperature in order to meet the temperature specification required at the final stand. The second reason we use the air jet is to raise the scale on the steel, permitting a better surface finish on the steel.

H. F. Lesso: Getting back to this critical dimension again, what have been your findings with reference to the importance of manganese chemistry versus this critical dimension?

N. E. Rothenthaler: In this low carbon strip our manganese specification is between 0.30 and 0.50 per cent. In that manganese range this critical dimension is not affected very much. On enamel iron you will find this effect, but I think what you have in mind, principally, is raising the manganese to reduce the granulation effect.

H. F. Lesso: Yes. Would you not find it much more important with a lower manganese range rather than a higher one?

N. E. Rothenthaler: That is true; as the manganese is reduced, you are liable to get more coarse grain, but between 0.30 and 0.50 per cent I do not think you find enough effect to give you any superior properties.

H. F. Lesso: What about residual silicon?

N. E. Rothenthaler: The maximum is 0.02 per cent; actually it averages about 0.01 per cent. The coarse grain effect is quite startling. Many metallurgists who are not fully acquainted with low carbon steel meet with considerable difficulty in annealing this steel subcritically. During the war, one shop was fabricating shell cases for which the bottom stamping was a cup about four inches high, made from hot rolled steel, 0.095 in. thick, which we supplied directly from our mill. They insisted on a normalized steel, so they had to arrange for outside facilities to normalize this steel. As you all know, during that period there were many different heat treating facilities which were converted for the heat treating of steel. This steel was shipped to a brick company which adapted a circular brick kiln to anneal this steel, using a temperature of 1500 F. When they got that steel on the job, they had the worst granulated steel I had ever seen.

RESULTS OF UNDERGROUND COAL GASIFICATION TEST SURPASS U. S. BUREAU OF MINES' EXPECTATIONS

▲ ECONOMIC studies to assess cost factors and gage the industrial significance of burning unmined coal to produce gas were recommended to the Bureau of Mines since the results of a joint experiment by the Alabama Power Company and the Bureau at Gorgas, Alabama, had surpassed expectations.

At Gorgas, where a block of coal was isolated and set afire with incendiary bombs under controlled conditions, the coal was burned out clean without wastage. The shale roof, made plastic by intense heat exceeding 2300 F, expanded and folded down gradually to occupy the space left by the consumed coal. Air needed for combustion continued to flow, however, between the rock-coal interface. The roof-rock or shale was particularly favorable for underground gasification, swelling to two or three times its original volume and still maintaining sufficient strength to hold up the overburden and prevent subsidence.

During the course of the 50-day project, 63 air-blast "runs" were made averaging 14 hours in length. To feed the flames at the base of a U-shaped tunnel, a blower pushed various concentrations of air and oxygen in at one portal while the gases were being trapped for careful analysis as they emerged at the other. Live steam blasts also were introduced alternately with air, for steam combines with carbon at high temperatures to produce the desired carbon monoxide and hydrogen. Gas qualities obtained were not as good as is deemed possible, in part because the light overburden and leakages prevented using air under high enough pressures. However, the gas was used for a small field boiler. Higher pressures, temperatures, and gas velocities, insuring quick removal of the gases before contaminating reactions occurred, would produce better quality gases.

In the excavating and mining conducted after the fire was extinguished to learn what had occurred underground, temperatures still exceeded 200 degrees even after steam was forced through the mine for five days and water for eight days in an effort to cool it. Workers were able to remain in the mine only for short periods, and once the still hot coal again burst into flame.

In driving adits and a bulldozer trench into the mine after the fire was extinguished, workers in turn encountered intact coal, slightly carbonized coal, coke, fused clay from bags which had been stacked along the tunnel to confine the flames, and then the folded and expanded roof material over a thin bed of ashes where the coal had been burned out completely. A problem remaining to be solved is a practical method for confining the flames to the desired area so that they will not encroach upon neighboring properties in any given coal bed, the conferees agreed. The clay bags proved inadequate.

Underground coal gasification, unlike most scientific problems, cannot be broken down into component parts and pursued in the laboratory. It must be done in the field on a fairly large scale. Any future experiment should approach a commercial-size operation encompassing perhaps 200 to 300 acres of coal land. As one method of attack to minimize initial mining costs, development plan involving the drilling of boreholes from the surface and the burning of the coal bed between them has been proposed.

Technical Program of the
AMERICAN IRON AND STEEL INSTITUTE

. . . . In reviewing the problems of postwar production and development, leading operators of the steel industry, at the fifty-fifth general meeting of the American Iron and Steel Institute held in New York City on May 21-22, presented a number of very interesting papers at the technical sessions. Special panels were held on "Coke Ovens, Blast Furnaces, and Steelmaking Furnaces"; "Raw Materials"; "Shaping and Forming"; and "General Metallurgy." Because of the value of the papers to industry, the following abstracts are presented . . . .

OPERATION OF THE IRON BLAST FURNACE AT HIGH PRESSURE

By J. H. SLATER, Assistant District Manager, Cleveland District, Republic Steel Corporation, Cleveland, Ohio

▲ Two furnaces of the Republic Steel Corporation under continuous pressure operation since August, 1946, have shown a substantial increase in efficiency over the usual low pressure operation. Through increase in average static pressure by increasing blowing pressure and throttling exhaust gases, it has been possible to decrease the velocity of gas through the furnace while blowing the furnace at substantially higher wind rates. Iron production has been increased 11 to 20 per cent, coke rates have been decreased of the order of 13 per cent, and flue dust production has been cut by approximately 30 per cent. These results are reflected in a manufacturing cost saving of over $1.00 per ton of iron.

DESCRIPTION OF PROCESS

The changes required in blast furnace construction to permit a furnace to be operated under high pressure are comparatively minor. In addition, the alterations are low cost (provided proper blowing equipment is available), totalling from $70,000 to $150,000 depending on the furnace. The construction changes consist of the following:

1. A one-piece hopper to insure a tight seat for the big bell. At the Cleveland No. 5 furnace the contacting surfaces of the bell and hopper are hard-surfaced. At Youngstown a standard bell and one-piece hopper are being used.
2. Equalizer valves operated to equalize the furnace and between-bell pressures when the big bell is dumped. Two systems are in use, that at Youngstown employing clean furnace gas from the wet washer for equalizing, and that at Cleveland utilizing dirty gas from the furnace.
3. Wet washer level, hand-operated control to prevent blowing of washer seal.
4. Throttling valve to regulate top pressure.

In addition, there are other lesser changes such as more hold-down rollers and extra weights on the McKee top and superior packing for the gage rod. Electrically operated, positively-seated bleeders are used on both furnaces.

No alterations are required on the cast house floor. However, a long trough is recommended so that proper slag metal separation can be obtained under the faster casting conditions existing.

The blowers utilized should be capable of blowing at higher pressures, a minimum of about 6 to 8 pounds above those normally used, at the same wind volume. In order to obtain the greatest return from pressure blowing, the blowers should also be capable of delivering substantially larger than normal volumes of air per minute to the furnace.

To operate the furnace under increased pressure, one merely regulates the throttling valve to control the top pressure of the furnace at the desired level. The hand settings and automatic control on the throttling valve maintain the top pressure remarkably constant, except during checking. The turbo blower is then adjusted to blow the desired amount of wind at the increased blast pressure required. Thus the average static pressure in the furnace can be considerably increased.

The dimensions and ratings of the Cleveland and Youngstown blast furnaces are as follows:

Of the two furnaces, the one at Cleveland is more ideally suited to trial operations because it is situated

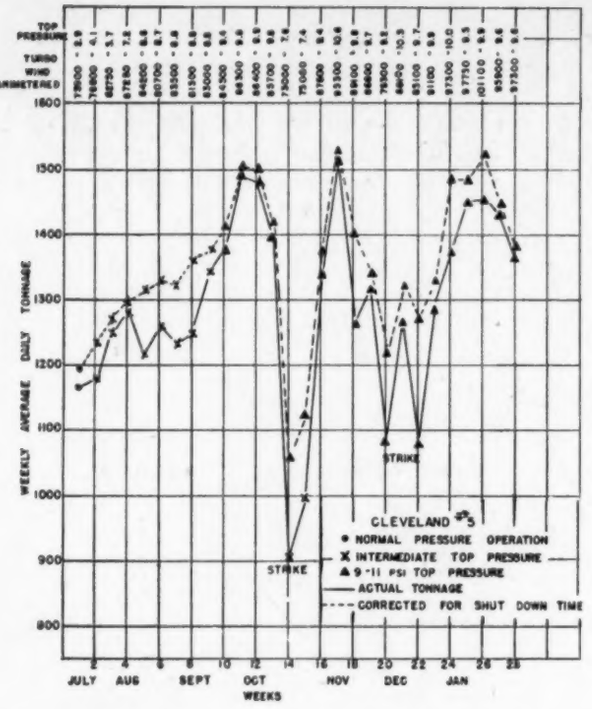


Figure 1 — Effect of pressure operation on iron production at Cleveland No. 5 furnace.

apart from other furnaces and all materials entering and leaving the furnace plant (with the exception of blast furnace slag) are weighed, thus permitting accurate material balances.

SUMMARY OF RESULTS

The present trial period of high pressure operation of the Cleveland No. 5 furnace began with its blow-in July 5, 1946, prior to which it had been shut down for 16 months. Data were taken beginning July 22 by which time the wind blown had been increased to the maximum for normal operation (75,000-85,000 cfm) and the furnace was producing satisfactorily. After 10 days of such normal operation the top pressure and wind blown were increased in steps, the method of operation of the furnace being altered (such as blast temperature, burden ratios, etc.) to take advantage of the high pressure conditions.

EFFECT OF PRESSURE OPERATION ON IRON PRODUCTION

The average daily production of pig iron for each week is plotted in Figure 1. The lower curve is the actual net tonnage produced, while the upper curve credits the furnace for tonnage during actual periods of lost time where the wind was taken completely off the furnace (such as during tuyere changes). At the top of the figure will be found the average wind blown and top pressure for each week. It should be noted that it has been possible to increase substantially the wind blown as the top pressure, and, therefore, the average pressure in the furnace, has been increased.

There are several points to note about the curve. In the first place, the tons of iron produced per day has increased from about 1170 (normal operation) to 1430 (pressure operation) at Cleveland.

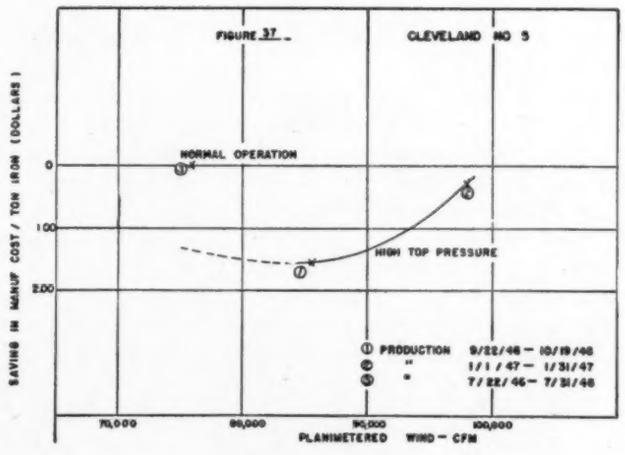
Another thing to note about Figure 1 is the irregularity of the average tonnages for the Cleveland furnace. As explained on the graph, this has been caused by two strikes, one being in the blooming mill and the other being the coal strike. In the case of the former, it was necessary to pig the iron so that production was limited to the capacity of the pig machine. In the case of the coal strike production became variable as the coke quality became erratic. The necessity of changing the coke mixture, using stock pile coal, which was oxidized and wet, and the use of longer coking time combined to give poor quality coke with as high as 15.5 per cent ash, and 1.9 per cent sulphur. The furnace never really settled down during these swings in burden, one of the contributing factors being the tuyeres which had just been increased in size in anticipation of blowing 100,000 cfm, so that they were oversize during the strike period.

The dry coke rate at Youngstown has decreased from approximately 1705 (normal operation) to 1485 at 10-11 psi top pressure, a saving of 220 lb per ton. At Cleveland the coke rate, omitting the strike periods, decreased from approximately 1750 (normal operation) to 1495 during the 4-week period in September-October, and to 1635 during the month of January, or a saving of 130 to 255 lb per ton.

EFFECT OF PRESSURE OPERATION ON FLUE DUST

The flue dust produced has decreased on both furnaces despite the large increase in wind blown. At Cleveland, where both flue dust and sludge are weighed, the amount of dust (dry) has decreased from 215-270 lb per ton of iron (normal operation at 77-83,000 cfm planimetered turbo wind) to 145 lb per ton during September-October (85,700 cfm wind and 10 psi top

Figure 2 — Savings in cost per ton of pig iron under certain conditions at the Cleveland No. 5 furnace.



pressure), and to 170 lb per ton during January (98,000 cfm wind and 10 psi top pressure). At Youngstown, where the dry dust is estimated by adding 25 per cent to the dust catcher weights to allow for the sludge which is not weighed, the dust has decreased from approximately 280 lb per ton of iron for normal operation (67,500 cfm planimetered turbo wind) to 240 lb per ton at 80,000 cfm wind and 10 psi top pressure.

The quality of iron produced has, in general, been higher and more uniform under pressure operation.

Steam consumption has increased at the higher blast pressures and wind volumes blown during pressure operation. At Cleveland the steam rate increased from 14.5 lb per 1000 cu ft of blast (normal operation, 76,800 cfm at 21.5 psi blast pressure) to 16.1 during the September-October operation when the wind was 85,700 cfm and the blast pressure 28.2 psi. At the same time the steam consumption increased from 1331 to 1374 lb per ton of iron.

It is interesting to note that, as the top pressure has been increased, and coke rates and gas velocities

TABLE I

	Cleveland No. 5	Youngstown No. 3
Hearth diameter	27′-0″	25′-6″
Bosh diameter	30′-0″	28′-3″
Stockline diameter	20′-0″	20′-0″
Large bell diameter	15′-0″	14′-6″
Total height	107′-8½″	105′-0″
Working height (tuyeres to 10′ stockline at Cleveland 9′ stockline at Youngstown)	82′-0⅜″	78′-4⅝″
Working volume	44,346 cu ft	39,016 cu ft
Bosh angle	83° 17′-32″	83° 19′-32″
Inwall Batter	1.0345 in./ft	1.091 in./ft
Ratio: Working volume to hearth area	80.75	79.47
Number of tuyeres	18	16
Rating, tons per day	1275	1120
Turbo blowers	2 — 90,000 cfm at 30 psi	90,000 cfm at 35 psi
Stoves	3 — 783,000 sq ft	4 — 365,750 sq ft

TABLE II

Cleveland No. 5

	Normal operation 1944	Normal operation 7/22-31, 1946	Pressure operation 9/22-10/19 1946	Pressure operation 1/1-1/31 1947
Iron, net tons per day, actual tonnage	1,273	1,169	1,435	1,422
Coke, lb (dry) per ton iron	1,673	1,746	1,494	1,635
Stone, lb per ton iron	951	973	824	1,018
Flue dust, lb (dry)/ton iron	270	213	145	170
Slag, lb per ton iron	1,098	1,156	1,143	1,125
Wind, cfm (turbo) Planimetered	83,200	76,800	85,700	98,000
Wind, cfm, calculated	78,000	72,200	73,400	83,000
Burden, ratio, wet	2.32	2.27	2.52	2.36
dry	2.57	2.40	2.68	2.57
Top pressure, psi	2.0	3.1	9.7	9.7
Blast pressure, psi	22.7	21.5	28.2	30.5
Top temperature, F	243	298	306	302
Blast temperature, F	917	936	1,191	1,043
Steam temperature, F	.....	678	684	670
Pressure, psi	.....	287	286	283
Flow, lb per day (27 in. vacuum)	.....	1,555,000	1,974,000	2,556,000
Rate, lb per 1000 cfm	.....	14.5	16.1	18.1
Lb steam per ton iron	.....	1,331	1,374	1,790
Wind off time, min per day	21	55	20	38
Checks	.....	5.1	6.9	17.3
Slips	.....	3.5	7.3	16.4
Top gas, CO/CO_2	1.90	.....	1.64	1.84
Btu per cu ft	89.3	.....	86.5	90.4
Coke analysis				
S	0.8	1.1	1.13	1.10
Ash	10.1	12.0	10.7	10.3
Moisture	10.3	5.3	5.6	8.2
Tumbler test				
on 2 inch	.....	0.5	3	1
On 1½ inch	.....	7	15	10
on 1	.....	25	37	36
on ½	.....	50	57	57
on ¼	.....	57	61	60

TABLE III

Heat Balances*

Btu per Ton of Pig Iron (Basis: 60 degrees F)

	Normal operation	10 psi top pres. operation
Heat generated		
Combustion of coke to CO at tuyeres	4,940,000	4,174,000
Blast heat	1,404,000	1,458,000
Heat from reduction reactions	376,000	367,000
Heat from slag formation	246,000	250,000
Total	6,966,000	6,249,000
Heat consumed		
Formation	94,000	92,000
Reduction of SiO, MnO & P_2O_5	292,000	279,000
Calcination of limestone	703,000	622,000
Decomposition of water	120,000	77,000
Heat to top gas	458,000	544,000
Evaporation of water	645,000	614,000
Heat to cooling water	329,000	225,000
Heat out in pig iron	1,036,000	1,004,000
Heat out in slag	920,000	933,000
Solution loss	1,035,000	1,060,000
Heat out in dust	9,000	7,000
Total	5,641,000	5,457,000
Heat unaccounted for	1,325,000	792,000

*Calculated by method similar to that proposed by Joseph and Bitsianes, Proc. Blast Furnace and Raw Materials Conf. A.I.M.E., 1944, p. 72.

through the furnace have decreased, there has been a corresponding drop in CO/CO_2 ratios.

Heat balances were made for the best monthly periods of normal and pressure operation, the results of which are tabulated in Table III.

The amount of delay or lost time on the furnaces when operated under pressure is of considerable interest in view of the mechanical difficulties encountered during the trials in 1944. In fact, this was usually the first concern of all the visitors who have come in some numbers from other steel companies to inspect the furnaces and quiz the operators. For this reason, detailed accounting was made of all lost time at both Cleveland and Youngstown. Before referring to table of these data, it should be emphasized that the times recorded are actual times taken from blast pressure charts where all checks on the furnace are evident and are not the times usually recorded by the burden clerk for the benefit of the management.

One of the few mechanical difficulties still remaining is the blowing out of the wet washer seal during slips when the furnace is at 10 psi top pressure. A design which will, by means of butterfly valves automatically operated in the outlet main and in the emergency overflow, maintain a nearly constant water level in washer, has just been completed and will be installed in the near future. It is expected this will eliminate any delay time and will also permit the furnaces to be operated at a substantially higher pressure.

DISCUSSION OF RESULTS

The detailed data collected over the past seven months on the two furnaces have been analyzed carefully in an attempt to learn which new variables introduced into blast furnace practice through operation at high pressure are responsible for the substantial improvement obtained in blast furnace performance.

Increasing the static pressure in a blast furnace allows the operator a choice in blowing he has not enjoyed previously. Thus, since increasing the pressure lowers the volume and increases the density proportionately at constant temperature, the operator can blow the furnace in any one of the following manners:

1. At a substantially increased wind rate (lb of air per minute) and maintain the same gas velocity through the furnace.
2. At the same wind rate and obtain a marked decrease in the gas velocity through the furnace.
3. At an intermediate condition with a moderate increase in wind rate accompanied by a decrease in gas velocity through the furnace.

It was expected from past experience with normal pressure operation that an increase in wind rate would burn more coke per minute and thus produce more pig iron per day. However, the decrease in coke rate obtained concurrently with the wind increase was not in accord with normal practice.

ECONOMIC BALANCE

One of the unique features of pressure operation is that it permits a flexibility of control never before available. Heretofore one could not blow a furnace on Lake ore at high wind rates without also having high coke rates and flue dust production. Low coke rates and flue dust could only be obtained by slack wind operation, which has the obvious disadvantage of low iron production. One can, through manipulation of average static furnace pressure and wind blown, control coke rate, iron production and flue dust production over a wide range.

Thus it is apparent that, for any top pressure, as the wind volume (hence velocity) is increased, the following changes in major manufacturing cost items take place: iron production increases to the point where a reversal occurs due to decrease in burden ratio with increase in velocity; coke rate increases; flue dust production increases; blowing cost increases; and gas credits increase. This immediately brings to mind the possibility of operation of the furnace at a point of optimum economic balance since some of the cost factors increase while others decrease. Therefore, calculations were made for three different conditions of the Cleveland No. 5 operation to determine whether such an optimum actually existed.

Actual cost figures are omitted as these would change from one manufacturer to another. However, the results of the calculations for the three conditions are plotted in Figure 2. It will be seen that an optimum for 10 psi top pressure probably occurs near the point for September-October operation where savings of approximately $1.50 per ton of iron were achieved. Thus it is assumed that for low wind operation (dotted line) the iron tonnage would be so low the cost above would become too high; and for the January operation the steam cost increase, and the coke cost increase (due to the higher velocity gases at the high wind rate) make the total

TABLE IV

Furnace Delay Time — Minutes per Week
August 1946 - February 1947

	Youngstown			Cleveland		
	First check	Second check	Wind off	First check	Second check	Wind off
Mechanical						
Gas washer repairs	1	5	6	1	1	4
Gage rod repairs	6	3	7	6	1	4
Change bleeder valve	..	..	27	..	..	32
Equalizer valve repairs	..	..	..	5	..	2
Operational						
Tuyere change	..	21	76	14	23	200
Unable to bott monkey	6	4	4	2	2	1
Burn through tuyere	..	9	3	..	..	..
Burn out monkey	..	3	..	..	..	..
Change monkey cooler	..	2	14	4	16	65
Pack monkey cooler	..	..	7	..	..	..
Blow wet washer seal	11	5	..	69	21	..

First check = ⅓ wind off Second check = ⅔ wind off

cost higher than that for September-October. In normal operation the operator is forced to take whatever burden ratio a particular wind volume blown permits him to carry, whereas, under varying pressure, one can adjust burden ratio, flue dust, and steam consumption to obtain optimum operating conditions. It is evident from Figure 2 that the Cleveland furnace should be operated at higher top pressure to obtain a higher burden ratio and greater cost advantage when blowing about 100,000 cfm wind.

CONCLUSIONS

Operation of the iron blast furnace at high pressure results in a significant increase in iron production, a marked decrease in coke rate, a decrease in flue dust produced, and a decrease in heat requirements per ton of pig iron. The efficiency of the process of reducing iron oxide in the blast furnace has been substantially increased. This is reflected in a manufacturing cost saving of over $1.00 per ton of iron.

Pressure operation permits a new flexibility in blast furnace practice which has not been possible heretofore. By manipulation of the pressure and wind blown, one can alter the velocity of the gases through the furnace over wide ranges. This new tool of variable velocity can then be used to control the iron production, coke rate, and flue dust production. Furthermore, this tool allows one to calculate for any given tonnage output possible, for a particular furnace and blower combination, the optimum point of operation for minimum cost per ton of iron, and permits the operator to maintain the furnace at that point.

Operation in the higher pressure ranges, which should effect lower coke rates, is unexplored. Further progress of large order of magnitude is already in sight. The largest blast furnace blowers ever constructed, 125,000 cfm at 40 psi, are now on order for use on pressure furnaces. They will allow operation up to 20-25 psi top pressure and should open up a new vista of blast furnace practice.

ITEMS OF CONTROLLABILITY IN THE OPEN HEARTH COMBUSTION PROCESS

By A. J. FISHER, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

▲ THE Sparrows Point plant of Bethlehem Steel Company started installing controls on open hearth furnaces in 1930. From that year until the present, we have been buying whenever possible, and developing, when necessary, various types and kinds of open hearth furnace controls. Throughout this period, we have maintained a more or less standard control with hand automatic and hand control defenses. They are easily understood by the furnace operators and have proved a negligible factor in respect to furnace delays.

We have recently established a plant tonnage record for our three open hearth shops during a recent months, as follows:

Shop	Tons tapped per heat	Hot metal per cent	Mo avg tons per fce	Gal oil per ton
1	164	49	11,981	25.05
2	188	46	14,041	23.58
3	200	51	15,419	21.70

Attention is called to the low per cent of hot metal used in the tabulated records. With higher percentages of hot metal, more tonnage could be attained with less fuel.

DESCRIPTION OF FURNACES

The following data on the No. 3 open hearth shop furnaces are most pertinent:

1. *Furnace refining chamber* — Heats of 200 net tons are tapped. The furnaces have refining chambers as shown by Figure 1, with a hearth area of 884 sq ft and a maximum of 3½ feet deep. The sprung arch roof consists of high quality 13½ inch thick silica brick and is 5 ft 3 in. above the highest bath level at the front of the furnace and 4 ft 2 in. at the back. The roof has a rise of 34 inches, a total inside span of 19 ft 11 in. from

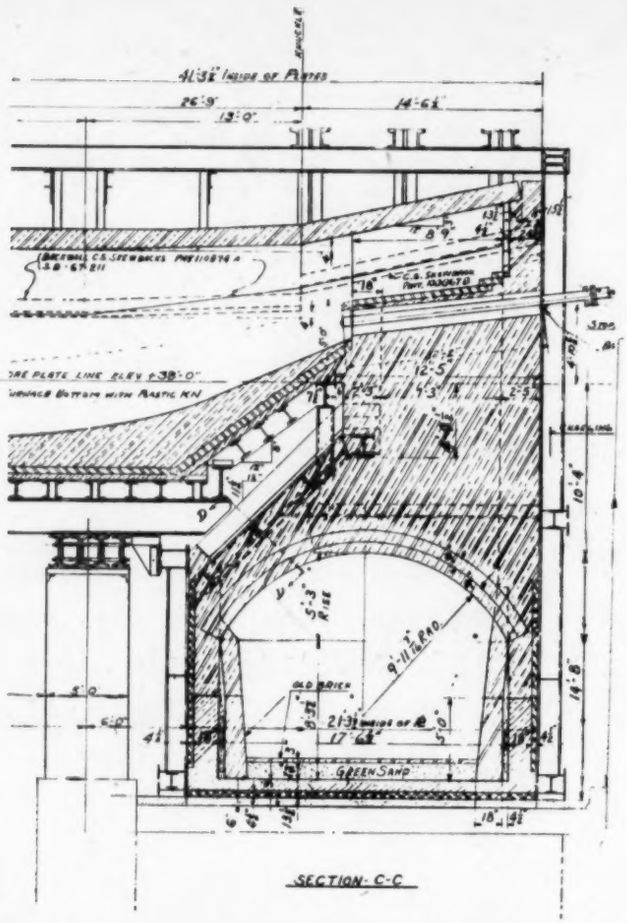


Figure 1 — Refining chamber of open hearth furnace.

front to back and 53 ft 6 in. from knuckle to knuckle. This gives a minimum volume of approximately 6800 cubic feet for combustion over the bath itself. The most severe erosion of the roof takes place in the area along the backwall, this section lasting approximately 100 heats. The wear at this point is due to the proximity of the bath and the channeling effect of the hot gases in the angle between the roof and the back wall. The front wall and back wall are composed entirely of basic brick. Combustion is balanced so that wear on the refractories in the various sections above floor level is nearly the same. In this way, furnace repairs are coincided, resulting in a minimum number of furnace delays.

2. *Furnace ends* — The point of maximum gas velocity is at the bridgewall area, just as the gases leave the combustion chamber. This area is approximately 60 square feet. The bridgewall and top of the burner housing are laid with basic brick while the furnace bulkheads, uptake, walls, arches and slag pocket construction are of silica brick. Because of the high gas velocities over the bridgewall, any improper combustion would result in excessive wear on the bulkheads. The rate of wear of the main roof is also quite critical, depending on combustion. The rest of the furnace refractories are relatively unaffected by improper combustion practices, although rate of boil up in the slag pockets and checker contamination may be adversely affected. The area of the uptakes at each end of the furnace is 86 square feet.

3. *Furnace checkers* — The No. 3 open hearth furnaces have double chamber two-pass checkers. The first passes are laid with 9 in. × 4½ in. × 3 in. first quality fireclay brick giving 7½ in. × 7½ in. square closed vertical checker flues. There are 400 of these flues per end with a total cross sectional area of 157 square feet, and a depth of 15 feet. The total heating surface is 15,000 square feet. The second pass checkers are laid with 13½ in. × 6 in. × 2½ in. first quality fireclay brick giving 5½ in. × 5½ in. square closed vertical checker flues. There are 430 second pass flues per end with a total cross sectional area of 91 square feet; the depth is 16½ feet. Total heating surface of the second pass is 12,980 square feet. This gives a total heating surface area of 27,980 square feet for both passes on one end of the furnace.

The flues from the second pass regenerators lead to 275 psi 600 F waste heat boilers with the usual induced draft fan.

In the background of any control system there must be well-trained instrument and control mechanics as well as combustion engineers. These men must operate out of an adequately designed instrument and control shop.

The fuel and control staff is as follows:

Combustion engineer	1
Asst. combustion engineer	1
Control mechanics	3
Instrument mechanics	3
Total	8

The panel board is the nerve center of the furnace. At this station, all controls are coordinated, and the furnace operations center at this place. Due to the metallurgical reactions in the furnace, and because the furnaces operate very closely to their refractory burning point, many of the controls are not completely automatic, but are of the hand-automatic variety. Equipment mounted on the panel board includes the following:

Single record oil flow recorder, single record combustion air flow recorder controller, steam pressure recorder, furnace pressure recorder controller, flue gas temperature recorder, combustion air temperature recorder, flame radiation recorder, manual control for oil flow, reverse timer, manual reverse control, and manual hydraulic valves to regulate boiler damper, stack damper, and combustion air.

Combustion air flow control is accomplished by means of a fan, venturi tube, vacuum pressure recorder controller, air hydraulic pilot valve, manual automatic seven-way oil valve, oil power cylinder and louvre air valve. The furnace is operated by constant air flow throughout the heat. Constant air flow makes a minimum of fuel reduction necessary when the furnace reaches the refractory burning point, and a reduction in heat input becomes necessary. This operating practice of maintaining constant air flow is only valuable in furnaces that can produce a high combustion air temperature of 2000 F and over.

Item No. 1 of uncontrollability is the effect of barometer, air temperature and humidity on the combustion air flow readings. Corrections must be made from time to time depending on these variables. In our plant they are made seasonably by the superintendent of each open hearth shop.

Item No. 2 of uncontrollability is air infiltration. Air

infiltration on the oncoming end cannot be measured. Much of it occurs during and after the regeneration cycle which lowers the final air preheat temperature. It causes more fuel to be burned, increases flue gas volumes and velocities and refractory erosion due to convection and temperature. On the outgoing end, air infiltration still further increases flue gas volumes, decreases flue gas temperatures, causes the waste heat boilers and their auxiliary equipment to be much larger than theoretically necessary and reduces the amount of heat recoverable in steam. Air infiltration is the one great drawback of the Siemens furnace.

The oil flow control is composed of two sections, the first is for metering and the second for control. Each section can be by-passed by means of three-way cocks for maintenance purposes; and in addition, both sections can be by-passed during power or control air failure.

The reversing cycle starts with a manually set fixed-time timer which operates relays, solenoid valves, time delay relays, etc. The complete reverse cycle, oil on to oil off, consumes 18 seconds. The timer is manually adjusted from 0 to 15 minutes and usually is set for 15 minutes reverse to hot metal and 10 minutes reverse from hot metal to tap.

Each open hearth shop will have a separate steam header for atomization purposes only. Steam will be fed into this header by means of an automatic reducing and desuperheating station from 275 psi 600 F steam. Steam pressure will be maintained at 160 psi; and steam temperatures will be varied to meet the various grades and kinds of fuel oil, depending on the flame radiation readings.

The furnace pressure control is composed of a temperature compensated pipe system from the furnace to the controlling instrument, recorder controller, air-hydraulic pilot valve, and two manual-automatic seven-way oil valves in parallel to two power cylinders, one to the flue damper and one to the louvre valve on the exhaust of the waste heat boiler fan. Either valve can be used for furnace pressure control depending on whether or not the waste heat boiler is in service.

Flue gas temperatures are measured by thermocouples in the four flues leading from the checker chambers to the waste heat boiler or stack. Pneumatic switches are used to cut out two of the thermocouples when combustion air is blown past them.

This record is used to keep the checkers balanced as to temperature by varying the volume of air distributed to each checker.

Combustion air temperature is measured by drawing a sample of air from the furnace uptake through a refractory tube by an inspirating eductor. The air sample flows around a closed-end refractory tube which is observed by a radiation tube sighted into this refractory target tube.

Flame radiation is recorded by means of two washed-air-blown radiation tubes in the key of the roof opposite the center line of the incoming doors. Therefore, radiation at both incoming and outgoing doors is recorded, the difference of which gives the efficiency of the furnace. It is interesting to note that the outgoing radiation tube records a function of furnace temperature and can be used as such for a guide in controlling maximum fuel input.

The tonnage and fuel rates of an open hearth furnace are functions of flame radiation to the bath in the early part of the flame development. The total Btu input will most always be burned in the furnace system before the checker chambers are reached. However, it is desirable by means of radiation, to transmit a large proportion of the heat of the fuel at the incoming end of the bath where the depth of the slag is minimum due to the flame physically pushing the slag to the far end of the furnace. Port construction, burners, barometer, temperature and humidity of the combustion air, pressure and temperature of the steam for atomization, and the temperature and kind of fuel oil, all have a bearing on flame radiation.

Item No. 3 of uncontrollability is the temperature of the steel before tapping. Although much activity is going on relative to this subject, both from thermocouples and radiation tube equipment, we have not been inclined to adopt one or the other until such time as further research and development make them more accurate and practical.

SUPERSONIC TESTING OF STEEL

By R. R. WEBSTER, Research Engineer, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

▲ SOUNDS you cannot hear are used to detect flaws in steel. High frequency sound waves, above the hearing limits of humans are a means of flaw detection. These sound waves, which are projected through the steel under examination, are affected by some types of defects and are thereby used to detect them. In one application of this supersonic testing, steel strip is continuously tested for laminations. In another application, using radar-like techniques, the detection and location of some type of deep flaws in wrought steel and cast steel is accomplished. The human ear is sensitive to sound in the frequency range of approximately 30 to 20,000 cycles per second In supersonic testing of metal, however, the frequency range of 500,000 to 12,000,000 cycles per second is used.

The supersonic method is applicable to the detection of blowholes, cracks, laminations, segregation and porosity. It is being used both in preventive maintenance and in routine inspection of steel products.

USE OF OXYGEN IN OPEN HEARTH PRACTICE FOR CARBON REDUCTION

By GEORGE V. SLOTTMAN, Manager, Technical Sales Division, Air Reduction Company, Inc., New York, and F. B. LOUNSBERRY, Vice President and Technical Director, Allegheny Ludlum Steel Corporation, Brackenridge, Pennsylvania

▲ THE reaction of oxygen with carbon is of fundamental importance in determining the duration of the refining period in steelmaking. This is particularly true in the manufacture of very low carbon steels, where refining periods of three hours or more are common practice and involve maintaining the furnace for long periods at temperatures approaching the safe limit of the refractories. Moreover, the rate of carbon drop appears to have a considerable influence on steel quality,

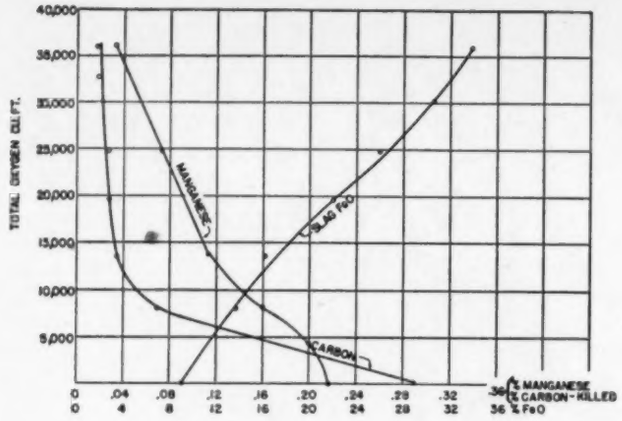


Figure 1 — Chart shows change of metal and slag analysis with the amount of oxygen blown.

the carbon monoxide evolving from the reaction assisting in degasifying the metal and in removing nonmetallic inclusions. The carbon-oxygen reaction thus has an important bearing not only on the economics of the open hearth process but also on the quality of steel produced, which accounts for the considerable amount of study now being devoted to this subject.

A comparison of the rates of carbon removal in the open hearth as against the bessemer process indicates that the rate of carbon is largely determined by the rate of oxygen supply to the metal bath, since carbon is removed in the bessemer at the rate of 16 per cent per hour (4 per cent in 15 minutes) as contrasted with (0.3-0.5) per cent per hour in the open hearth.

The first practical large scale application of oxygen to the open hearth bath was made in August, 1946, at the Brackenridge plant of the Allegheny Ludlum Steel Corporation. In the course of this work, metallurgical studies were made of the factors governing the rate of carbon removal, and the economics of the oxygen blow, which afford comparisons with the normal practice of removing carbon by the action of an oxidizing slag.

FACTORS AFFECTING THE RATE OF CARBON DROP

In the normal oxidizing slag practice, the rate of decarburization is determined by four factors: (1) the rate of supply of oxygen to the slag, from ore or furnace gases, (2) the rate of diffusion of oxygen from the slag to the metal, (3) the rate of the reaction of carbon and oxygen, and (4) the ability of the reaction product carbon monoxide to escape from the steel. In addition, the over-all effect of bath temperature on the course of these reactions must be considered. Considerable difference of opinion exists as to which of these reactions exerts the greatest influence on the rate of decarburization.

EXPERIMENTAL PROGRAM

A series of experimental heats using gaseous oxygen were therefore made in a 90-ton furnace at the Brackenridge plant, operating on all cold charges with baths melting clear at 0.3-0.6 per cent carbon. Refining was formerly done under highly oxidizing slags to produce steels of 0.02-0.03 per cent carbon content. In the test heats, charges consisted of 85,000 pounds of basic pig iron, 93,000 pounds of Grade A open hearth rolled scrap, 22,000 pounds of silicon steel scrap and 16,500 pounds of limestone. No ore was added either in the charge or during the heat, and the only addition made was small quantities of fluorspar. At the end of the lime boil, oxygen was added to the bath through a one-inch diameter pipe at various constant rates of flow. Analyses were made of the carbon, manganese, phosphorus and sulphur content of the bath at suitable intervals during the oxygen blow, and corresponding slag samples were taken and analyzed for FeO, Fe_2O_3, CaO, SiO_2, MnO, MgO, P_2O_5 and Al_2O_3. Some wedge tests were taken and analyzed for oxygen, nitrogen and hydrogen by vacuum fusion. Additional heats were made using two pipes simultaneously, and some study was made of the normal rate of carbon drop without oxygen.

Some difficulty was experienced in interpreting the data because of interruptions in the blowing time occasioned by the charging floor traffic as well as by the time required to change pipes. Slag volumes were calculated by manganese balance and an oxygen balance made to determine the oxygen pickup from the gases. Since it was apparent that a substantial weight of oxygen was entering the slag-metal system from the furnace's gases, an estimate was made of this factor and the blowing time corrected to include it. It was estimated that the rate of oxygen pickup from the furnace atmosphere is some 480 pounds of oxygen per hour. Tests were made of the rate of carbon drop after blowing and indicated a drop of 0.07 per cent carbon in 20 minutes at 0.30 per cent carbon, which would require an input of over 8.4 pounds of oxygen per minute to the steel. As a correction factor, the value of 10 pounds of oxygen per minute entering the slag-metal system from the furnace atmosphere was used and corresponds to a rate of carbon drop in higher carbon ranges of 0.25 per cent per hour. This value was applied as a constant correction factor over all carbon ranges, and although this value may appear somewhat high, it was purposely chosen so as to be conservative with respect to the effect of gaseous oxygen. In applying this correction factor, the blowing time was increased by the total time of the reduction period multiplied by ten, divided by the rate at which gaseous oxygen was supplied. The effect of applying this correction factor is to give lower decarburization rates, which are directly related to the rate of blowing oxygen.

Figure 1 illustrates the type of data obtained by plotting the slag and metal analyses against the oxygen blowing time, with an oxygen pressure at the lance pipe of 90 pounds per square inch, corresponding to a flow of 695 cubic feet or 57.3 pounds of oxygen per minute.

The rate of carbon drop falls slowly as the carbon content is lowered to the region of 0.10 per cent carbon, and then decreases rapidly at lower carbons. The manganese content decreases slowly until the carbon content falls below 0.10 per cent and then falls rapidly with the increasing oxygen content of the metal.

THE RATE OF CARBON DROP

The rate of oxygen supply was varied from 27 pounds (330 cubic feet) to 62 pounds (810 cubic feet) per minute, with an effective blowing time amounting to 45-75 per cent of the total blowing period. In the higher carbon ranges, the evolution of carbon monoxide from the bath was generally distributed over the entire bath area. As the carbon fell below 0.10 per cent, the activity of the boil diminished sharply and was concentrated around the point of immersion of the lance pipe.

Table I contains the corrected rates of carbon drop and the efficiency factor corresponding to the different rates of blowing oxygen input for a constant rate of oxygen input from the furnace gases as previously discussed. These data indicate that the rate of carbon elimination varies with the rate of oxygen input, and that the efficiency factor expressed as pounds of carbon removed per pound of oxygen input is relatively independent of the rate of oxygen input, but varies largely with the bath carbon. The effect of the correction for oxygen pickup from the furnace atmosphere is to lower both the apparent rates of decarburization as well as the efficiency factors calculated therefrom.

Since the efficiency factor reaches a maximum of 0.75, corresponding to the ratio of the atomic weights of carbon and oxygen, an examination of the data shows that in carbon ranges above 0.40 per cent, oxygen added directly to the bath reacts almost quantitatively with carbon and other alloying elements. With carbon contents below 0.25 per cent the decarburizing efficiency of oxygen diminishes rapidly, and in the region below 0.05 per cent carbon the bulk of oxygen is entering the slag as iron oxide diffusing or precipitating from the metal.

THE MECHANISM OF THE OXYGEN BOIL

A clear understanding of the mechanism of the oxygen-carbon-manganese reaction is important not only from a theoretical point of view. It has a very practical significance in determining the desired carbon end point. Particularly in the lower carbon ranges, where rapid estimates of bath carbon content cannot be made, any method which would permit of calculating the oxygen requirement to obtain a desired carbon content would be extremely useful. Given such a mathematical approach, it would then be possible to add metered amounts of oxygen to the bath and to predict the change in carbon content as well as the time required for the decarburization. Attempts were therefore made to interpret the rate and efficiency data obtained by means of the equations commonly used for correlating rate of carbon drop and bath carbon content.

The rate equation proposed by Schenck has the form:

$$\frac{dc}{dt} = k_1 (O) (C) — K_2 pCO$$

where the rate of carbon drop is proportional to the product of the oxygen and carbon contents less a function of the back pressure of the carbon monoxide formed. This equation presupposes a concentration of oxygen in the steel at a level (ΔO) above the equilibrium value. Os is the oxygen content of steel at saturation assumed to be 0.23 per cent oxygen at 0.012 per cent carbon for temperatures in the open hearth range. Oc is the oxygen content corresponding to equilibrium at any carbon level. The equilibrium value of $C \times O$ was taken at 0.0028.

The mechanism of the oxygen blow indicates that there is no simple relation which will correlate the rate of carbon drop with the rate of oxygen input for all slag metal conditions, except at very high rates of oxygen input and where the distance through which the oxygen must diffuse to reach the body of the metal is small. In the very low carbon range it is obvious that the efficiency can be improved by providing a large number of points of injection, covering the entire bath area, a condition which is approached in the bottom blown bessemer.

PRACTICAL APPLICATION

In order to obtain consistent results in decarburizing with gaseous oxygen, particularly in low carbon ranges,

TABLE I

Rate of Carbon Drop and Efficiency Factor (Corrected Blowing Time)

Carbon content— %		0.25		0.20		0.15		0.10		0.075		0.05		0.04		0.03		0.025		0.02	
Heat No.	Lb of oxygen per minute	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.	$\frac{dc}{dt}$ 10^{-3}	Eff.
6577	27	8.4	0.55	6.9	0.46	5.4	0.36	2.8	0.19	2.0	0.13	1.2	0.079	0.80	0.053	.....	.....	.....	.....	.....	.....
6578	34	9.4	0.50	6.6	0.35	4.4	0.24	2.4	0.13	1.7	0.09	1.1	0.058	0.78	0.041	.....	.....	.....	.....	.....	.....
6579	40	15.5	0.68	11	0.50	7.8	0.35	4.7	0.21	2.9	0.13	1.6	0.073	1.1	0.050	0.48	0.022	.....	.....	.....	.....
6580	46	14.6	0.57	11	0.44	7.7	0.30	3.7	0.14	2.8	0.10	1.6	0.062	1.0	0.040	0.62	0.024	0.30	0.011	.....	.....
6582	53	.....	.....	17	0.59	11	0.37	6.3	0.22	3.5	0.12	2.1	0.071	1.5	0.052	0.76	0.026	0.34	0.010	.....	.....
6584	57	.....	.....	17	0.53	12	0.38	6.8	0.21	4.4	0.14	2.8	0.088	2.1	0.068	0.81	0.025	0.42	0.013	.....	.....
6585	57	21	0.66	16	0.52	11	0.33	6.5	0.20	4.6	0.14	3.1	0.097	2.2	0.068	0.78	0.024	0.39	0.012	0.08	0.0025
6588	62	.....	.....	23	0.67	14	0.42	8.3	0.27	5.5	0.16	2.9	0.084	1.9	0.055	0.90	0.025	0.41	0.011	.....	.....
Average efficiency factor			0.59		0.51		0.35		0.20		0.13		0.077		0.053		0.024		0.011		0.0025

it is therefore essential to control the rate of oxygen supply, the percentage of effective blowing time, the volume of metal to slag and the slag basicity. Bath temperature at the start of the blow should also be at a constant level corresponding to the initial carbon content. Under such conditions and provided that all the oxygen supplied enters the bath, the time required to decarburize between given carbon levels can be accurately forecast, and the volume of oxygen required quantitatively added to the bath.

In attempting to evaluate the practical advantages of using oxygen versus iron ore for carbon reduction in open hearth practices, several factors must be considered.

1. The original charge.
2. The objective desired.
3. The degree of carbon (and other metalloid) reduction.
4. The plant facilities available for furnace charging and for metal and slag handling.
5. The cost of iron ore.
6. The cost of oxygen.
7. Labor cost and method of compensation.
8. Yields.

Inasmuch as all of these factors will vary with individual plants, any attempted evaluation in dollars and cents would be misleading and confusing. The advantages in the use of oxygen versus iron ore can be expressed in percentages as representing the experiences of Allegheny Ludlum at Brackenridge, Pennsylvania, in low carbon practice.

Since August, 1946, which was the last full month using 100 per cent iron ore for carbon reduction, until January 1, 1947, a total of 664 open hearth heats were made using oxygen in whole or in part for carbon reduction. Assuming the ingot tons produced per production hour worked in August as 100 per cent, the gain in September was 17 per cent when 40 per cent of the heats melted were carbon reduced with oxygen. In October, a gain of 30 per cent was obtained when 100 per cent of the heats melted were carbon reduced with oxygen. In November, 23 per cent gain with 96 per cent of the heats melted on oxygen and 23 per cent in December with 98 per cent of the heats on oxygen. Depending on the type of heat melted and the end point desired, it can be safely estimated that a gain of 25 to 35 per cent in ingot tons produced per production hour worked can be obtained using oxygen versus iron ore for carbon reduction.

The saving in time per heat has varied from two hours to as much as four or five hours, again depending on the type of heat melted and the end point desired. It is indicated that the saving in the cost of iron ore required plus the cost in fuel saved will more than offset the cost of oxygen used to accomplish the same result, leaving the increased tonnage obtained per production hour worked as clear gain.

Except for one or two mishaps largely due to inexperience in the use of oxygen, no serious trouble has been experienced with furnace bottoms, roofs or side walls. It is indicated that refractory cost per ingot ton produced will be less largely due to the shorter time the bath and furnace are exposed to high temperature in carrying out the carbon reduction.

An interesting advantage in the use of oxygen versus iron ore is the effect on yield from metallic weight charge to ingot weight cast. Here again there is considerable variation depending upon the type of heat melted and end point desired, but will show from 1 per cent to as high as 4 per cent increase in yield. The over-all average is approximately 2 per cent increase in yield using oxygen versus iron ore in making over 600 heats.

To date it can be said that the average quality is higher and in no case has it been lower. As more experience is gained and more control in the use of oxygen is developed, it is indicated that the average quality will be definitely improved and the comparative cost will be definitely reduced.

SUMMARY

The average bath oxygen content was found to be within the range of oxygen contents common to normal slag metal practice. The oxygen content of the slag was found to vary with the reciprocal of the bath carbon content and appeared to be affected by the rate of blowing.

In interpreting the data obtained, the diffusion factor (Os-Oc) and the effect of oxygen entering the slag from the metal were considered to be the dominant influences on the rate of carbon and manganese removal. The equation which will cover the experimental data is in the form $\frac{dc}{dt} = 0.03 \frac{do}{dt} \frac{(Os-Oc)}{Oc}$.

For constant rates of blowing and for constant slag-metal conditions, the time of blow and the weight of oxygen supply can be predetermined in reducing carbon between any desired limits.

A DESIGN FOR BLAST FURNACE HEARTHS

By W. S. UNGER, Consulting Engineer, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania

▲ GOOD hearth design carries with it two corollaries: first, proper selection of the materials used in the construction, and second, careful and intelligent operation.

As a basis for this discussion, it might be well to consider some of the furnaces which have been built by the Carnegie-Illinois Steel Corporation in the last decade, where the conditions surrounding their building have been such as to cause not too great a compromise with best design and where the scope of the designer has not been unduly limited. Such a tabulation is shown in Table I.

The daily rated capacity of a furnace is calculated from its hearth area, being the hearth area multiplied by a factor that varies according to the raw materials available for the district under consideration. For furnaces in the Pittsburgh district which consume coke made from 100 per cent high volatile coal and an average grade of limestone, 2.24 is the factor used, whereas, for the Chicago district, which consumes coke made from a mixture of high and low volatile coals and a good

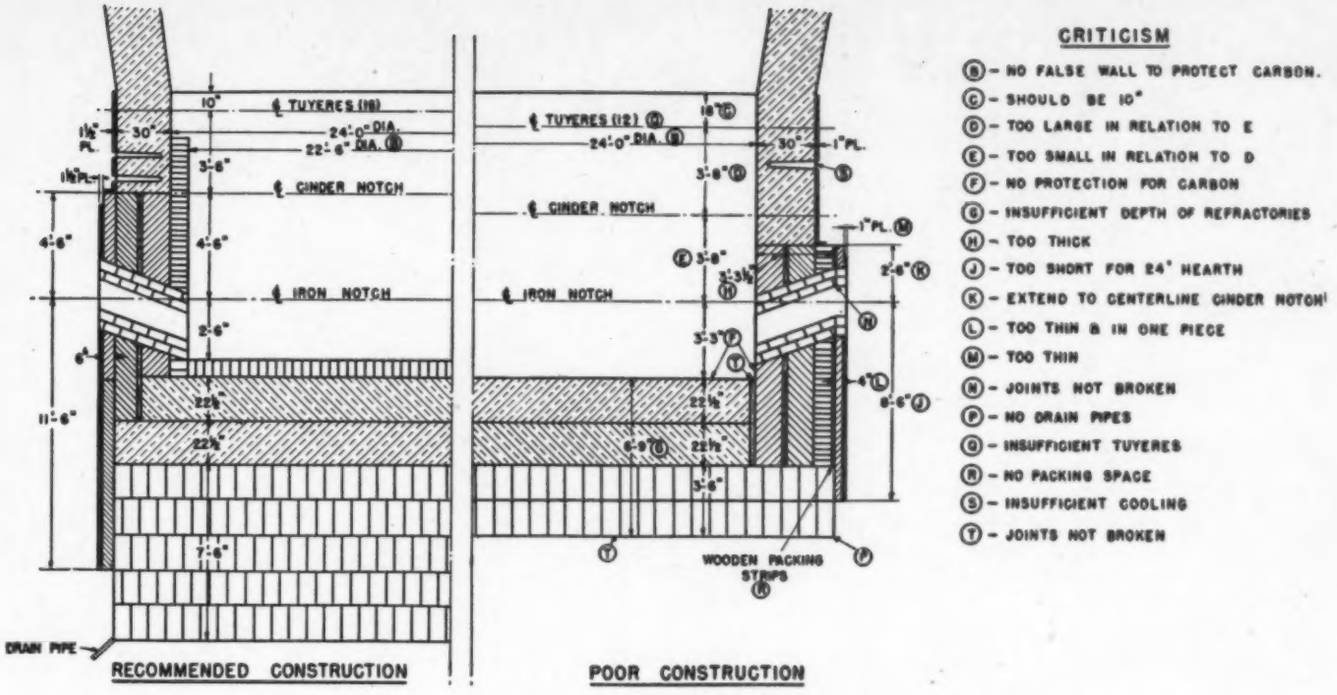

CRITICISM
(B) - NO FALSE WALL TO PROTECT CARBON.
(C) - SHOULD BE 10"
(D) - TOO LARGE IN RELATION TO E
(E) - TOO SMALL IN RELATION TO D
(F) - NO PROTECTION FOR CARBON
(G) - INSUFFICIENT DEPTH OF REFRACTORIES
(H) - TOO THICK
(J) - TOO SHORT FOR 24' HEARTH
(K) - EXTEND TO CENTERLINE CINDER NOTCH
(L) - TOO THIN & IN ONE PIECE
(M) - TOO THIN
(N) - JOINTS NOT BROKEN
(P) - NO DRAIN PIPES
(Q) - INSUFFICIENT TUYERES
(R) - NO PACKING SPACE
(S) - INSUFFICIENT COOLING
(T) - JOINTS NOT BROKEN
TUYERES (18)
24'-0" DIA.
22'-6" DIA.
CINDER NOTCH
IRON NOTCH
DRAIN PIPE
RECOMMENDED CONSTRUCTION
TUYERES (12)
WOODEN PACKING STRIPS
POOR CONSTRUCTION

Figure 1 — On left is shown recommended blast furnace construction and on right is shown construction which is not recommended.

grade of limestone, 2.45 is the factor used. If this method of obtaining the capacity of a furnace is used, an empirical formula may be derived to obtain the distance between the center line of the iron notch and the center line of the cinder notch (distance E). It is expected that the hearth of the furnace should have the ability to contain the iron which normally would be produced by 1.8 casts. Also, the iron should not be allowed to rise to the center line of the cinder notch, otherwise there would be danger of the iron attacking the cinder notch cooler; therefore, this level should be held approximately 10 in. below the center line of cinder notch which represents the distance from the center line to the lower edge of the cinder notch cooler.

Volume between center line iron notch and 10 in. below center line cinder notch = 1.8 tons iron per cast multiplied by volume iron per ton.

$$\frac{(\text{E in inches}-10\text{ in.})\ (\text{hearth area})}{12} = \frac{1.8\ (\text{Factor})\ (\text{hearth area})}{24} \times \frac{24}{\text{No. Casts per Day}} \times \frac{2000}{450}$$

$$(\text{E in inches}-10\text{ in.}) = \frac{96\ (\text{Factor})}{\text{No. Casts per Day}}$$

$$\text{E in inches} = \frac{96\ (\text{Factor})}{\text{No. Casts per Day}} + 10\text{ in.}$$

Since the factor for ferromanganese is approximately .9, a furnace designed for iron practice but producing erromanganese could be cast twice a day with no more danger than casting it five times a day on iron practice. Conversely, if an iron furnace were operated on high top pressure or on oxygen enriched blast, the number of casts per day should be increased. If it were originally contemplated to operate a furnace on high top pressure or oxygen enriched blast, it would be preferable to design the furnace, using the proper factor for the tonnage expected, which would automatically increase the distance between the iron notch and the cinder notch, resulting in a more normal casting schedule.

The distance between the center line of the cinder notch and the center line of the tuyeres (distance D) must be considered in conjunction with the distance from the center line of the iron notch to the center line of the cinder notch (distance E). For present slag volumes the distance between the center line of the cinder notch and the center line of the tuyeres (distance D) should be approximately 75 per cent of the distance between the iron notch and the cinder notch (distance E). If the slag volume varies from 0.6 ton slag per ton of iron, this percentage should be modified accordingly. For example, if the slag volume were 0.5 ton per ton iron, this percentage would become 62.5 per cent.

It is felt that the distance between the center line of the iron notch and the top of the bottom refractories should be between 30 and 36 inches. This distance would permit changing the grade of iron quickly because of the small size of the dominant pool and would permit flushing more cinder through the cinder notch, thereby running less cinder at cast with the consequent detrimental slag action on the hole. A slight decrease of the ferro-static head on the bottom would result.

It is felt that the bosh should start about at the top of the tuyere cooler or approximately 10 inches above the center line of the tuyeres (distance C), as this

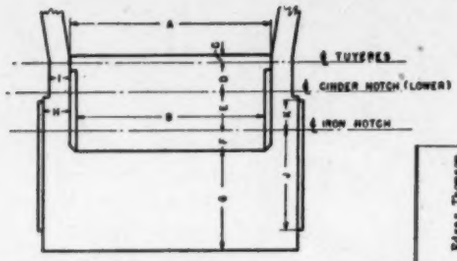


TABLE 1.

	Edgar Thomson 1 & 2	Edgar Thomson 3	Duquesne 4	Carrie 3 & 4	Carrie 6 & 7	Clairton 1	Ohio 2	Gary 6 South 11 & 12	South 4 & 8	South 10	Gary 7	Gary 8	Gary 11 & 12
1. Diameter A (Nose to Nose Tuyere Coolers)	27'-6"	26'-0"	23'-0"	26'-0"	23'-6"	23'-0"	25'-0"	28'-0"	25'-9"	24'-6"	26'-6"	25'-6"	25'-0"
2. " B (Face to Face Brick)	"	"	"	"	"	"	"	26'-6"	25'-0"	23'-9"	"	"	"
3. Area at A Sq.Ft.	594	531	415	531	434	415	491	616	521	471	552	511	491
4. " " B Sq.Ft.	"	"	"	"	"	"	"	552	491	443	"	"	"
5. Height C (℄ Tuyere to Top Hearth)	9-1/2"	9-1/2"	9-1/2"	9"	9"	21"	12"	11"	21"	21"	12"	12"	12"
6. " D (℄ Tuyere to Cinder Notch ℄)	3'-3-1/2"	3'-4"	3'-2"	3'-6"	3'-3"	2'-9"	3'-0"	3'-8"	3'-4"	3'-4"	3'-4"	3'-9"	3'-9"
7. " E (℄ Cinder Notch to ℄ Iron Notch)	4'-8"	4'-8"	4'-5"	4'-3"	4'-3"	4'-9"	4'-6"	4'-8"	4'-8"	4'-8"	4'-2"	3'-9"	3'-9"
8. " F (℄ Iron Notch to Top Bottom Block) (Note 1)	3'-3"	3'-6"	2'-10"	3'-0"	3'-0"	2'-10"	1'-6"	3'-3"	2'-3"	2'-3"	2'-0"	2'-0"	2'-0"
9. " G (Depth of Bottom Brick) (Note 2)	15'-0"	12'-0"	10'-6"	16'-0"	15'-3"	13'-8-1/4"	7'-6"	15'-0"	15'-0"	13'-0"	15'-0"	13'-6"	13'-6"
10. Distance H (Thickness Hearth at Staves)	36"	36"	Var.	45"	40"	36"	31-1/2"	33"	36"	36"	42"	30"	30"
11. " I (Thickness Hearth at Tuyeres)	31-1/2"	36"	31-1/2"	33"	27"	27"	31-1/2"	27"	27"	27"	27"	27"	27"
12. Height J (℄ Iron Notch to Bottom Stave)	10'-9"	8'-3"	-	10'-9"	8'-6-1/2"	9'-1"	6'-9"	11'-4"	10'-9"	10'-9"	13'-9"	11'-2"	11'-2"
13. " K (℄ Iron Notch to Top Stave)	3'-9"	3'-9"	-	3'-9"	3'-0"	2'-8"	5'-2-1/2"	4'-8"	3'-4"	3'-4"	1'-9"	1'-10"	1'-10"
14. Total Height of Stave (J + K)	14'-6"	12'-0"	14'-2"	14'-6"	11'-6-1/2"	11'-9"	11'-11-1/2"	16'-0"	14'-1"	14'-1"	15'-6"	13'-0"	13'-0"
15. Thickness Cooling Stave (Note 3)	5"	5"	5-1/2"	6"	5"	6"	4"	6"	5"	5"	5"	3"	3"
16. Number of Cinder Notches	2	2	1	2	2	1	1	2	2	2	1	2	1
17. " Tuyeres	18	16	16	16	15	16	16	20	14	12	18	12	12
18. " Columns	9	8	8	8	10	8	8	10	14	12	9	8	8
19. Rate of Production N.T./Day	1330	1189	931	1189	972	931	1100	1509	1276	1155	1351	1252	1203
20. Hearth Area per Tuyere (Line 3 ÷ Line 15)	33.0	33.2	25.9	33.2	28.9	25.9	30.7	30.8	37.2	32.3	30.7	42.6	40.9
21. Feet Hearth Circumference per Tuyere	4.50	5.11	4.52	5.11	4.92	4.52	4.91	4.40	5.78	6.41	4.63	6.68	6.55
22. Volume Tuyeres to ° Cinder Notch Cu.Ft.	1955	1770	1314	1859	1411	1141	1473	2259	1736	1570	1840	1916	1841
23. Volume Cinder Notch to Iron Notch Cu.Ft.	2772	2478	1833	2257	1845	1971	2210	2875	2432	2198	2300	1916	1841
24. Volume Tuyeres to Iron Notch Cu.Ft.	4727	4248	3147	4106	3256	3112	3683	5134	4168	3768	4140	3832	3682
25. Volume Iron Produced/Hour Cu.Ft.	246	220	172	220	180	172	204	279	236	214	250	232	223
26. Volume Cinder Produced/Hour (Note 4) Cu.Ft.	1968	1760	1376	1760	1440	1376	1632	2232	1888	1712	2000	1856	1784
27. Volume Iron & Cinder Produced/Hour Cu.Ft.	2214	1980	1548	1980	1620	1548	1836	2511	2124	1926	2250	2088	2007
28. Theoretical Holding Capacity for Cinder (22 ÷ 26) Hrs.	.99	1.01	.85	.94	.98	.83	.90	1.01	.92	.92	.92	1.03	1.03
29. " " " " Iron (23 ÷ 25) Hrs.	11.3	11.3	10.7	10.2	10.2	11.5	10.8	10.3	10.3	10.3	9.2	8.3	8.3
30. " " " " Cinder & Iron(24 ÷ 27) Hrs.	2.13	2.14	2.03	2.07	2.01	2.01	2.01	2.04	1.97	1.95	1.84	1.84	1.84
31. Actual Holding Capacity for Cinder & Iron (Note 5) Hrs.	9.2	9.2	8.6	8.2	8.2	9.4	8.8	8.4	8.4	8.4	7.3	6.4	6.4
Note 1. Including Sillimanite Pad Thickness	3"	6"	9"	-	-	-	-	-	-	-	-	-	-
Note 2. Excluding Carbon Pad Thickness	-	-	-	-	-	15-3/4"	-	-	-	-	-	-	-
" " Carbon Bottom	No	No	No	No	Yes	No	No	Yes	No	No	No	No	No
Note 3. Double Row of Staves	No	No	No	No	No	No	No	No	No	No	Yes	No	No
Note 4. Based on 1200# Cinder/Ton Iron and 150# Cinder/Cu. Ft.													
Note 5. Based on line 3 x [line 7 - 10" (1/2 dia. nose cooler)] + line 25 and iron level down to iron notch after cast.													

distance represents about one half of the diameter of the tuyere cooler at the nose.

Some furnaces have a false lining inside the regular lining from the tuyeres coolers downward (diameter B). The false lining is universally used with carbon sidewalls and sometimes with firebrick sidewalls, but in either case it is expected to last only a few hours and to protect the sidewalls until they are heated to their normal operating temperature. The sidewalls on blowing out (distance H and I) are usually found to be worn back until stopped by the cooling effect of the stave or copper cooling plate. For this reason the thickness of the sidewalls at tuyere level (distance I) and at a stave level (distance H) should be the same and need not be over 30 inches. There might be a tendency to slight the cooling in the area just above the staves, so it is recommended that the copper cooling plates be installed not over nine inches above the top of the cooling staves.

The cooling stave, sometimes called the hearth jacket, the jacket, or hearth plate, cools a large area of the hearth and deserves careful consideration. It should be a minimum of five inches in thickness, and its length should depend upon the hearth diameter. Its length above the center line of the iron notch (distance K) should be such as to reach to the bottom or to the center line of the cinder notch cooler. Its length below the center line of the iron notch (distance J) = A/2—0.5, with a minimum of 10 ft.

There are two methods in use for determining the number of tuyeres required — the first being the circumferential distance between the tuyeres, and the second being the square feet of hearth area per tuyere. The second method is preferred, and a furnace designed with 25 to 30 square feet of hearth area per tuyere should produce optimum results. This presupposes that the other dimensions of the furnace above the hearth are in proper proportion.

Figure 1 shows recommended construction and a construction which is not recommended.

DESIGN OF A MILL FOR ROLLING SEMI-FINISHED PRODUCTS

By J. J. CURTIN, Superintendent of Rolling Mills, Bethlehem Steel Company, Lackawanna, New York

▲ WHEN studying the design of a mill for rolling semifinished products the following factors must be considered:

1. Size of product to be rolled.
2. Source of steel supply.
3. Quality of product.
4. Tonnage required.

When these factors have been established we are ready to consider features of design, bearing in mind that these conditions must be met at the lowest possible cost. Here a certain increase in installation cost may be offset by a lower operating cost.

Where a mill is supplied directly from a blooming mill and where the entire output of the bloomer is to be rolled, the mill capacity should be slightly higher — 10 per cent or so — than that of the blooming mill.

In general there are three basic types of semifinishing mills. First, the continuous mill which follows and

operates in line with the blooming mill. Depending upon the size range of the products, the continuous mill usually consists of one or two trains, each made up of four to six stands. The larger train will usually have rolls ranging from 26 to 32 in. in diameter and the smaller train from 18 to 22 in.

The second type is the cross country mill, which normally is made up of a two-high reversing roughing mill, of 32 to 36 in. diameter roll size, following a bloomer, and in turn, followed by two cross country stands, 28 to 32 in. diameter roll size, with the two stands on a common drive.

The third type is the older and less common three-high billet mill, arranged in tandem with a two-high reversing bloomer.

Each type of mill has a specific place in the industry, depending upon the answers to the four basic questions given previously. Regardless of the type of the semi-finishing mill, the chief requisites for practically all semifinished tonnage are freedom from surface defects, reasonable accuracy in size and weight of sections, and straightness of product, the latter being particularly important in the case of billets.

Let us first consider the continuous mill, the advantages of which are many. High tonnage output and low labor costs are the principal benefits. Rolling temperatures can be closely controlled; oxidation and scale losses are lower due to rapid reduction of the metal; efficiency in regard to pass utilization is high since all passes work to full capacity; roll breakage is small and longer blooms can generally be used, thus reducing crops on the billets and improving yields.

The principal disadvantages are the relatively high installation cost and the large number of rolls which must be stocked for this type of mill. There is also some lack of flexibility of sections that can be rolled for any given roll setting, and, due to the multiplicity of stands, roll changing requires much time. Complicated, accurate sections give the roll designer many problems in the continuous mill and such a product should really not be considered for this type of mill.

The advantages of the cross country type mill are that it produces billets of very good quality. As the bars drop free after each pass there is no twisting between passes, and guide scratches are nonexistent. Furthermore, this type of mill may also be used for other products, such as: rails, structural sections and large bars. The cross country mill is particularly well adapted to the rolling of quality products in a very wide range of sections. Initial construction cost is comparable to that of a continuous mill, but roll costs are much lower due to the smaller number of stands employed.

While the cross country mill is very flexible in its range of sections it has the disadvantages of greater heat losses and additional scale losses during rolling, while the shorter length of blooms which can be used means additional crop with resultant lower yields. Likewise, labor costs are higher compared with the continuous mill. More space and larger buildings are usually required for this type of mill, which again makes its construction cost relatively high.

The third type of mill will require only brief comment. The 3-high type of semifinishing mill has the advantage of lower installation cost, but it is limited in its tonnage capacity, in the moderate elongations obtainable, and in the minimum size billet that can be rolled. Its fixed passes reduce the flexibility of the sizes rolled. If the ingot is cut into two or three pieces to make it suitable for rolling, the pieces must be rolled at different temperatures, resulting in variations in section, scale losses will increase and the extra crop ends will reduce yields. The limitations of the 3-high billet mill from a tonnage standpoint places very definite restrictions on its application in a modern steel plant.

Some comparison should be made between the three types of mills discussed. However, exactly how to make such a comparison is rather a difficult question.

It therefore seems best to set down the difference in the yield "bloom to billet" delivered on the hot bed, eliminating from the figure any rejections; in other words, to consider only the difference caused by the items previously mentioned.

Yield — Blooms to billets on cooling bed:

Continuous mills	X
2-High reversing, 3-high finishing	X minus 0.9 per cent
Cross country with reheaters	X minus 1.4 per cent

Operating costs are also difficult to compare due to different methods of accounting. This item can be best expressed in "man-hours per ton of product." These figures include all electrical and mechanical maintenance men:

	Man-hours per ton of product
Continuous mills	0.36
2-High rougher, 3-high finishing	0.822
Cross country with reheaters	0.95

Installation costs vary with the market. However, the relationship of the cost of each mill can be recorded. Assuming we have power sources and consider the cost as including engineering, excavating, foundations, sewers, roads, buildings and machinery, the comparative cost of these mills would be:

Continuous mill	1.5 X
2-High rougher, 3-high finishing	X
Cross country with reheaters	1.75 X

THE JOLIET COARSE ROD MILL

By R. R. SNOW, Division Superintendent, Hot Mills, American Steel and Wire Company, Joliet, Illinois

▲ BECAUSE there are many sizes of billets in use and a great many rod sizes required and also because there are a good many ideas as to how to best accomplish the conversion of billets to rods, there are very few rod mills that are duplicates.

The design of a rod mill is governed largely by the work it is expected to do. If it is to roll nothing but No. 5 rod, the design will be different than if it is to roll nothing but coarse rod. Likewise a rod mill designed to roll a wide range of sizes will differ from one intended to roll a very narrow range. In other words, a new rod mill is really "tailor made" for a specific job. This job is determined by sales and other surveys before the mill is designed. It is often possible to roll sizes or

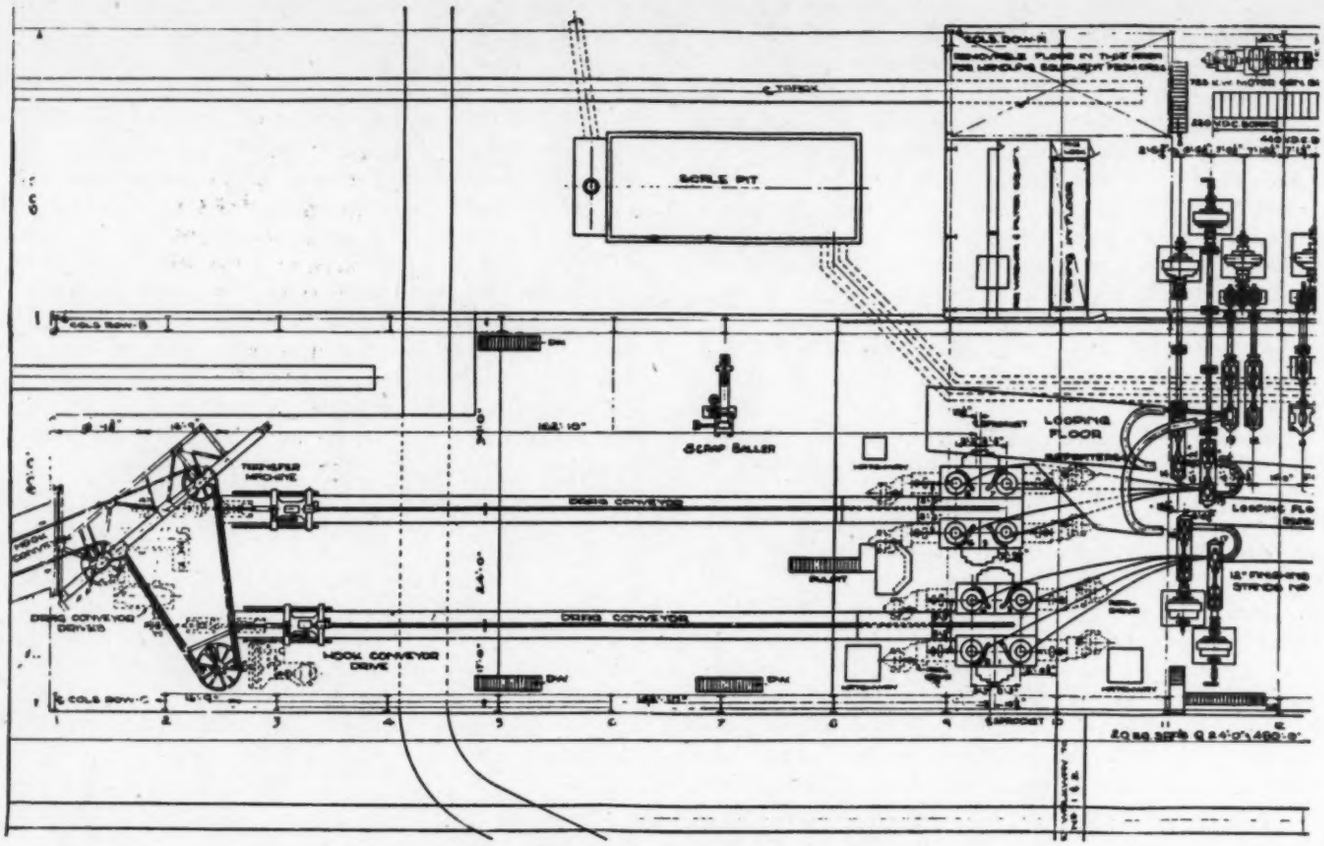


Figure 1 — Layout of Joliet Coarse Rod Mill.

shapes not contemplated when the mill was designed, but these usually result in higher costs or a sacrifice in quality.

The Joliet coarse rod mill was designed for high production of quality rods from 2½ in. × 2½ in. × 30 ft billets over a range of rod sizes from $\frac{11}{32}$ to $\frac{55}{64}$ in., inclusive. It has proved to be an exceptionally good mill as regards both production and quality and consequently it is also a low cost mill.

Bessemer, basic open hearth, and electric furnace steels are rolled with a carbon range of from 0.05 to 0.90. In addition to a great variety of plain carbon steels, alloy and some stainless steels are rolled.

The mill has averaged over 280 tons per 8 hour turn for a period of months and the production is still on the increase.

The overall billet to rod yield averages about 93 per cent. All rods are inspected and trimmed. Between 50 and 60 per cent of the production is upsetting steel and about 15 per cent is high carbon upsetting steel, chiefly SAE 1038 grade.

During the strike year of 1946 the mill produced approximately 179,000 tons of rods. Of this production, 88,000 tons was processed in our own wire mills and 90,000 tons shipped directly to the trade. The percentage of scrapped or returned rods from both our own and customer plants was approximately one-tenth of one per cent of the total production.

The Joliet coarse rod mill furnace is a 60-ton continuous furnace. It is a two-zone furnace, having 13 burners in the preheat zone and 16 burners in the soaking zone. This provides the necessary flexibility to cover rolling rates, which vary from 25 net tons per hour to 80 net tons per hour. The furnace is equipped to burn natural gas or oil.

The mill proper consists of five 16 in. roughing stands, six 14 in. intermediate stands and two 12 in. finishing stands arranged in tandem, followed by a large and a small repeater which carry the finishing squares to two separate 12 in. finishing oval stands. Two oval repeaters then carry the finishing ovals to two separate 12 in. finishing round stands. A semirotary type flying shear is located after the ninth stand.

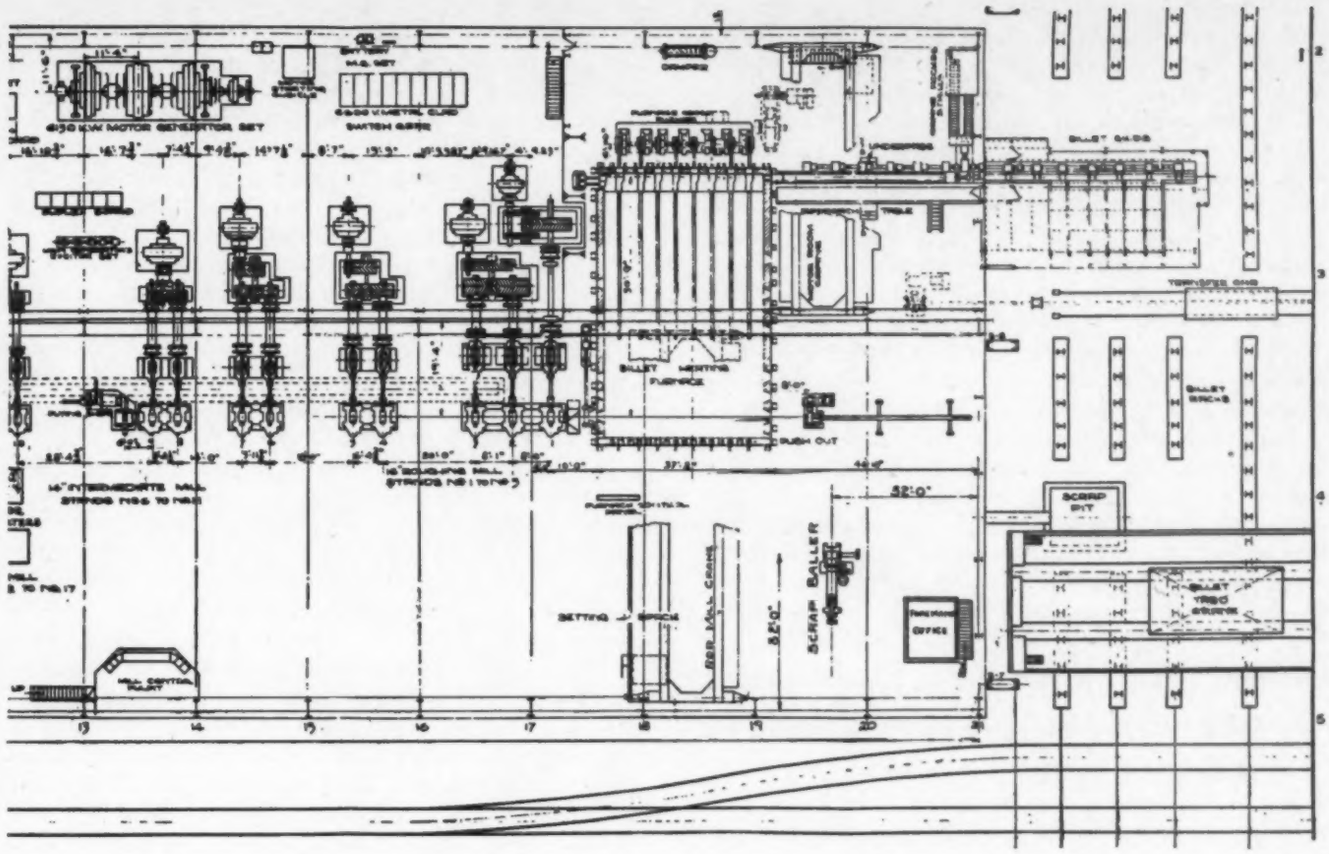
To provide the flexibility required to cover the range of sizes rolled, the first stand is driven by a separate motor and the balance of the stands in the continuous part of the mill are grouped two stands to a motor. The four looping stands are each equipped with separate motors. All motors are direct current and the total horsepower of the motors is 9500.

The speed of the various motors is controlled from a pulpit above the mill floor in a centrally located position. In this motor control room are coarse and fine controls for each motor as well as voltage controls which are used to speed up or slow down the entire mill as a unit.

The pass sequence used is the common oval, square, oval, etc. However, the first two stands are both ovals to provide greater flexibility. A and B passes are employed to cover the range of sizes rolled. The finishing round passes vary by 64ths up to ¾ in. size and 32nds above this.

Grain rolls are used in the first 8 stands and chill rolls are used in the rest.

Four pass lines are set up through the continuous



part of the mill, and two passes are set up in each finishing oval and round for all sizes under ½ inch. These sizes are rolled 3-line. There are two reasons for employing the 4-line set-up for 3-line rolling; one is that the distribution of the 3 lines between the two finishing sets may be done right at the furnace by the mill feeder with a 4-way switching table, and the other is that a full three lines can be rolled because the usual need for spacing between billets is taken care of by the 4-line set-up.

Sizes ½ in. and greater are rolled 2-line. The 2-line tonnage on these larger sizes is limited by furnace or motor capacity and there is the advantage of single line finishing which is considerable on large rods.

The mill is equipped throughout with roller bearings. With this type of bearing there is no mill adjustment necessary for bearing wear and the only adjustment needed, once the mill is set for a given stock and size, is that required to compensate for the wear on the passes.

All roll stands are equipped with worm and worm wheel adjusting mechanism for the top roll which is used for all vertical adjustments. Both top and bottom rolls may be moved in or out from the working side of the mill and will hold their setting, which is another decided advantage derived from roller bearings. On a high tonnage coarse rod mill such as this, which covers a large range of sizes, numerous roll changes are inevitable, particularly on the so-called "big end" of the schedule. Here the sizes are fast and the orders per size are small. To keep roll change time to a minimum, fourteen space roll stands are provided. These are set up by a roll assemblyman prior to the changes and are placed in the mill by an overhead crane as needed.

Eight individual electrically driven and controlled reels are employed to handle the production of the mill. These are arranged in groups of four, one group for each finishing stand. The reels are controlled from a reel pulpit about 15 feet above floor level located between the two drag conveyors. All reel switching is done with solenoid operated switch pipes.

MILL CREW

The mill crew (charging table to transfer machine) consists of 23 men per turn, including the roller. In addition to these there are 4 maintenance men who maintain and repair all electrical and mechanical equipment included in the billet yard, mill, and rod docks.

THE TRAINING OF METALLURGISTS FOR THE STEEL INDUSTRY

By JOHN CHIPMAN, Professor in Charge, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Massachusetts

▲ ALTHOUGH the steel industry has experienced for several years an acute shortage of technically trained personnel in the younger brackets, the current deficit

in engineering graduates cannot be liquidated earlier than in 1952. The ability of the universities to supply the metallurgical industries with adequately trained metallurgists depends on: (a) continued industry-university cooperation; (b) incentives provided by industry for metallurgical graduates; and (c) abilities of the schools to hold competent instructors. Many educators feel that science and technology have become too complex to be taught in the traditional four-year period, and that at least one more year is essential. Moreover, the post-graduate training programs of industry may have to be changed to offer training in metallurgical science and in the physics and chemistry on which it rests, and also training in research by the actual doing of research. The results of such research form an important part of the scientific basis upon which the industry operates; but the more important product is the trained researcher. Employment of such men is the industry's assurance that it will possess the ability to understand and to translate into profit the results of research all along the scientific front.

PROGRESS IN THE MANUFACTURE OF STEEL PIPE WITH PARTICULAR REFERENCE TO SEAMLESS PIPE

By E. N. SANDERS, Vice President, Operations, National Tube Company, Pittsburgh, Pennsylvania

▲ THE National Tube Company is in process of building a mill at Lorain, Ohio for the manufacture of seamless pipe and tubing in sizes below 4½ in. outside diameter at production rates unattainable on existing conventional seamless mills, and with design features which will permit the rolling of seamless tubes of lighter walls and with dimensional tolerances not possible on the conventional or automatic seamless mills.

The improved operating efficiency of seamless units has up to now been reflected to a much greater degree in sizes over 4½ in. diameter than in the size range under 4½ in. Because of inherent characteristics which have been associated with the conventional seamless manufacturing method, the product of this process has has not been competitive in cost with the small sizes of standard pipe which constitute 87 per cent of this market and about 35 per cent of the total tonnage of pipe produced in the United States. To permit seamless pipe to be competitive in this market required a reduction in the cost of material, as well as conversion cost. Economies are being effected through designing this new seamless mill to utilize much larger sized rounds than heretofore for the same pipe size. A parallel installation of a high production blooming and bar mill will give the desired results.

Since the weight of a round bar increases as the square of its diameter, and the surface only as the diameter, it will be evident that these larger rounds have reduced the amount of surface to be conditioned and thus have decreased the loss of material in the surface preparation. The reduced area to be conditioned, together with an improvement in surface which has been brought about by developments in mold preparation and teeming practice, have effected further economies in the manufacture of seamless tube rounds.

Improvement in the quality of heating, reduction in labor, and an incidental reduction of 65 per cent of the scale loss formerly incurred, represent the most attractive features of the rotary hearth furnace. This reduced scaling reflects a 2 per cent saving in the over-all cost of material. Full use of this modern type of equipment is being made on the new seamless mill.

Without changing the roll surface speed or the feed angle, modifications which have been made in the piercing pass have increased the delivery speed of the piercing mill 100 per cent. This development in piercer pass design makes it possible to use lower cost steel and has substantially increased the productive capacity of the piercing mill. In the manufacture of seamless tubes, the operation of piercing is followed in present day practice by processing through a rolling mill over a plug to elongate and reduce the wall. Material is then processed through a reeling machine for improving the wall dimensions, and finally through a sizing mill designed to reduce the outside diameter of the pipe to specified size.

The process which is being utilized in the seamless mill now under construction employs two operations entirely different in characteristics from those of the conventional process and which replace those operations just mentioned. The first of these which replaces the hi-mill, is the continuous tube rolling mill which consists of nine tandem, individually powered stands of two-high grooved rolls. The rolls in the consecutive stands have their axes at 90 degrees with each other. The motors driving these roll stands aggregate 8500 hp. Essentially the continuous tube rolling mill is similar to the modern strip mill in that the product passes progressively from stand to stand. The chief difference is that the tube mill requires an internal mandrel against which the work piece is rolled to reduce wall thickness.

This cylindrical mandrel extends entirely through the pierced billet and passes through the mill with the work piece. In the first two roll stands, the diameter of the pierced billet is reduced so that the inner surface is in substantial contact with the mandrel bar. Each of the next two stands makes a reduction in wall over a portion of the circumference, the two jointly completing the first increment of reduction. The next two stands, the fifth and sixth in this mill, make a similar complete reduction of somewhat less magnitude. The next two succeeding stands (7 and 8) are designed to effect a very slight reduction, the purpose being to planish the tube surface.

The shape of the tube which has been oval in the preceding stands is changed to circular section in the ninth stand. The rounding up operation effected by this stand frees the inner surface of the tube from the mandrel bar to facilitate withdrawal of the mandrel. This mill will deliver pipe in 65 ft lengths at rates up to 900 fpm. The over-all wall reduction which will be made in the continuous rolling mill is approximately twice that now made in the conventional two-high mill. As a result of this increased wall reduction, the productive capacity of the piercing mill has been stepped up.

The second operation, which replaces the reeling and sizing operations of the present day seamless mill, is a tension reducing or stretch mill. After withdrawal of

the mandrel, the rolled tubes are reheated before they are processed in the tension reducing mill. This mill, which is similar in construction to the continuous rolling mill, consists of sixteen two-high roll stands with individual stands powered by 200 hp motors. Tension reducing, which has recently been developed by the company, is unique in that without the use of a supporting mandrel the wall thickness is diminished while the diameter is reduced. This operation differs from the conventional reducing mill in which the wall thickness of the tube is increased as the diameter is reduced. In the tension reducing mill the tension forces to which the tube is subjected between roll stands are not only effective in reducing the wall thickness of the tube but, in addition, make possible diameter reductions in successive stands more than 20 per cent greater than can be made in the conventional mill. The faculty of permitting the entering tube wall to be maintained or reduced while large diameter reductions are being made in successive stands permits a single entering tube size to be employed for the production of all tube sizes in the size range 3½ to 0.675 in. outside diameter. This unit therefore permits production at approximately constant tonnage regardless of the diameter being produced. To insure continuous operation, a second sizing mill is being provided to be utilized during roll change periods.

The seamless unit now under construction has a rated monthly capacity of 18,000 tons and will produce seamless pipe in the size range 2 to 4 in. inclusive. The arrangement will allow the size range to be extended downward to include ⅜ in. pipe size. The economies provided by the continuous seamless mill will be further augmented by the latest developments in mechanized handling and machining, and by recently installed warehousing facilities which will permit each size to be produced to volume quantity. By means of this new equipment, quality seamless pipe will be produced at a cost far below present costs on conventional mills.

THE METALLURGY OF COLD REDUCED SHEETS

By C. L. ALTENBURGER, Research Engineer, Great Lakes Steel Corporation, Detroit, Michigan

▲ IN addition to taking the required shape without cracking or showing surface blemishes, cold reduced sheets must possess sufficient strength for the needs of the shaped product, and in many applications retain a smooth surface for painting or other type of coating.

In developing the properties of cold reduced sheet, the steelmakers must guard against a chain of adverse conditions ranging from excessive sulphur in the raw materials to excessive gas evolution from the molten steel while it is being teemed or poured into ingot molds. Furthermore, the minute amounts of impurities or unwanted elements and compounds remaining in the ingot must be so uniformly distributed that they do not weaken the finished sheet steel nor mar its very smooth surface.

The term "cold reduced" applies to the continuous rolling operations that reduce the thickness of the steel by as much as 80 per cent. Although the steel is cold before it is reduced, the friction and stretching of the steel during the rolling operations may raise its temperature to 500 F.

THE OUTLOOK IN MERCHANT PIG IRON

By BERTRAM S. STEPHENSON, President, Tonawanda Iron Corporation, North Tonawanda, New York

▲ AS LONG as iron, steel and foundry industries hold at or near their present rates of operation, merchant pig iron will continue critically short. Even allowing for some shifting of blast furnace capacity from steelmaking and alloy grades to merchant grades, the available tonnage of merchant iron will not sustain a production of gray iron and malleable castings much, if any, above the rate recently attained. Continuance of the current acute scarcity of scrap for both steel plant and foundry use will only serve to prolong and accentuate the present shortage of merchant iron. Merchant iron requirements for the nation's 3400 foundries are estimated at 230,000 net tons for steel foundries, 400,000 tons for malleable foundries, and 5,000,000 tons for gray iron foundries. The amount of merchant pig iron required for nonintegrated steel producers will depend to a large degree on the volume of scrap that will be available to them. If scrap regains its prewar status of adequate supply and dependable quality, this would enable steel furnaces to get along with less pig iron, and thus divert more blast furnace capacity to merchant iron production.

CARBONIZATION OF COAL SPRAYED WITH OIL

By PAUL C. MAYFIELD, Superintendent, Coke Plant, Alan Wood Steel Company, Swedeland, Pennsylvania

▲ IN 1931, Alan Wood Steel Company was faced with the probability of a large inventory of coke. This fact caused serious consideration to be given to means for maintaining a maximum gas make with a minimum of coke production. Accordingly, the decision was made to experiment with the spraying of heavy oils, such as gas enrichment or bunker "C" on the coal to be carbonized. Oil was taken from the bottom of a storage tank, pumped through a one and a half inch loop to a point immediately after the mixing belts and just ahead of the hammer-mill, the excess returning to the storage tank.

No difficulty was experienced in conveying or charging the oil treated coal, nor was there any noticeable evidence of oil on the belts. No difficulty was experienced in pushing the coke. There was no apparent change in the structure or appearance of the coke, although there were some traces of lamp black deposit on the coke surface in the fractures.

The quantity of oil used per ton of coal was started off with one gallon and gradually increased to 2½ gallons per ton or about one per cent of the coal weight. Some indications of oil were noticed on the oven benches, having seeped through the oven door luting and,

no doubt, was caused primarily by the comparatively low flue temperatures.

The type of oil used first was that known as gas enrichment oil and was selected because that particular type was in common use in the manufacture of carburetted water gas and it was believed it would probably give the maximum gas yield per gallon.

It is rather difficult to determine accurately the increase in gas, tar and light oil yields, due to the application of oil. The month of December 1931 was assumed to be a normal month as far as yields were concerned, before the use of oil was begun, and the change was taken to be the result of the oil addition. These changes appeared to be approximately as follows, per gallon of oil:

Gas — 115 cu ft at 530 Btu
Tar — 0.4 gallon
Light oil — 0.07 gallon

There was no apparent change in gas analysis.

The indicated production of tar was somewhat higher than expected. This was probably due to long coking time on the ovens, which would tend to produce more tar and less gas.

After several months' use of gas enrichment oil, it was decided to change to bunker "C" as the cost was somewhat less than that of gas enrichment oil. There was no noticeable difference in yields as a result of having made the change to bunker "C".

In 1941, experiments were undertaken to see what effect the application of small quantities of oil would have in the control of bulk density. The results obtained proved rather startling as it was found that the weight of coal per cubic foot could be increased by as much as six to eight per cent by the addition of not more than one-half pint of oil per ton of coal. The oil used was absorbent oil taken from the circulating system of the light oil recovery plant.

It is our practice to spray an amount of oil which will maintain the bulk density very close to 47 pounds per cubic foot, as determined by the ASTM method. It appears that the maximum density of coal is obtained at about 0.20-0.25 per cent of oil by weight to coal charged.

Thus the use of oil on coal has two very definite results, namely:

1. Small quantities for the use of control of bulk density result in the increase of amount of coal per charge. This should be approached in a cautious manner to keep from possible difficulties in pushing the charges from the ovens.
2. The use of large quantities of oil, say up to 1 per cent or more by weight, will pass the point of maximum coal density. Additional increase of oil will cause the density of the coal to be further decreased until it will again approach the weight per cubic foot it may have had before the addition of any oil. The use of additional oil is limited by the following conditions:
   a. Oil seepage at the doors.
   b. Oil soaking of the regenerator walls.

EXPERIMENTS TO IMPROVE COKE STRENGTH

By CHARLES W. STAHL, Research Engineer, Bethlehem Steel Company, Bethlehem, Pennsylvania

▲ ALONG with uniformity, blast furnace operators generally agree that the most important property of blast furnace coke is its strength (i.e. its ability to resist degradation in the blast furnace).

As a result of these meetings a program of coke testing was initiated with emphasis on sampling and frequency of tests. To make certain that the samples were representative of the coke going to specific furnaces, they were taken at the furnace skips. The primary objective was to endeavor to correlate the effect in the blast furnace of one property — coke strength.

Using the ASTM tumbler stability test as a measure of coke strength, the 200 coking tests run in our two experimental ovens in the present program have yielded some very useful information:

1. Both test ovens produce cokes having practically the same stability values. Moreover, good correlation results when comparing this property with cokes from plant production.
2. The tests confirm that coal quality is the most important variable affecting coke strength, see Table I. This was shown in a series of tests on 9 different coal mixtures pulverized 85 per cent through the ⅛ in. screen. Each mixture contained 65 per cent of the same high volatile coal and 35 per cent of different low volatile coals. The 9 tests produced cokes which differed in stability index from 30.5 to 44.6.
3. A series of coal mixes were tested to find the optimum percentage of one of our low volatile coals to be used in order to produce the strongest coke possible with available high volatile coals. The graph of Figure 1 shows that blending 75 per cent of this

Figure 1 — Effect on coke strength caused by blending low volatile coal into mixture.

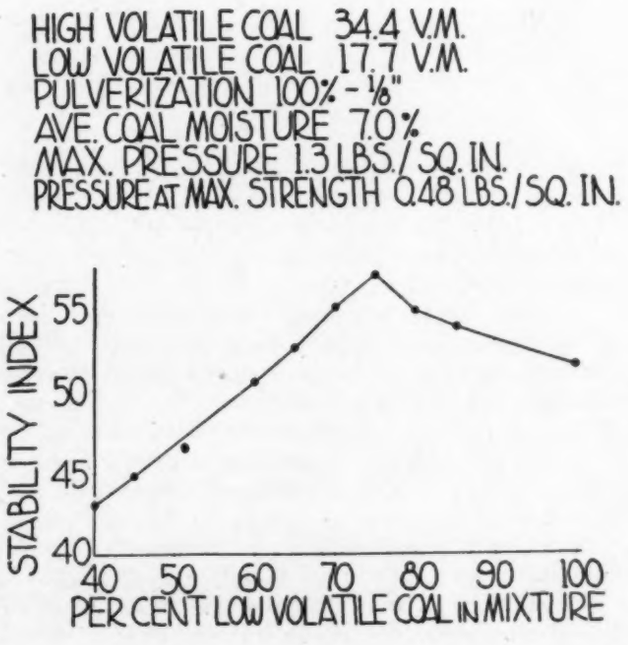


TABLE I

Test Results Using 9 Different Low Volatile Coals with 65 Per Cent of Pittsburgh Seam High Volatile Coal

Low volatile coal No.	Avg flue temp F	Coal center F	Coking time		Coal pulverization % - ⅛ in.	Low volatile coal analyses				Coal moisture %	Coke screen test			Tumbler test		Max oven press psi	Coke		
			Hr	Min		V.M.	F.C.	Ash	S		+4″	+3″	+2″	Stability	Hardness		V.M.	F.C.	Ash
1	2092	1800	6	5	85.13	24.70	64.25	11.05	1.72	5.0	3.60	21.05	53.20	30.50	58.61	0.07	2.11	81.71	16.18
2	2122	1800	5	54	86.98	21.78	69.32	8.90	0.86	5.3	6.33	28.27	46.91	32.48	59.48	0.16	1.82	83.60	14.58
3	2107	1800	6	35	83.43	20.38	71.22	8.40	1.66	4.4	4.29	23.63	51.05	33.37	60.98	1.06	2.23	82.51	15.26
4	2067	1800	6	31	82.60	23.70	69.72	6.58		5.6	6.84	28.22	48.09	34.23	61.91	0.15	2.66	82.72	14.62
5	2108	1800	5	53	87.30	24.00	64.30	11.70	0.86	4.9	4.74	27.25	48.35	37.71	61.09	1.48	2.06	81.08	16.87
6	2115	1800	6	24	86.75	20.52	67.94	11.54	2.05		7.42	29.25	45.80	38.91	60.69	0.30	1.66	83.86	14.49
7	2122	1800	6	28	90.25	17.36	70.24	12.38	1.59	5.7	5.15	34.67	45.11	43.70	61.75	0.46	1.48	83.10	15.42
8	2093	1800	6	2	86.35	18.22	75.12	6.66	1.62	6.1	9.35	35.20	39.76	44.21	59.32	0.31	2.81	83.49	13.71
9	2062	1800	6	57	86.37	21.46	67.80	10.74	0.84	4.35	8.71	33.29	44.37	44.63	63.16	0.99	1.73	83.28	14.99

low volatile coal into the mixture yielded the strongest coke and that further additions actually weakened the coke. The maximum pressure developed in this series was 1.3 psi and occurred when using 100 per cent low volatile coal. The reversal in this curve indicates the importance of testing a wide range of proportions of the coals to be used. Other coals would probably show different trends.

4. The tests confirm that finer pulverization improves coke strength.

A METHOD OF ESTIMATING BLAST FURNACE PRODUCTION AND COKE CONSUMPTION

By W. E. MARSHALL, Supervising Metallurgist, American Rolling Mill Company, Middletown, Ohio

▲ THE development of the simultaneous equations used in this method is rather laborious, but once this has been done and the results accepted, their application to a problem is relatively simple.

On the basis of pure reason alone it would appear to be true that:

$$T = \frac{G}{X}$$

where T = tons pig iron produced per day

G = pounds of coke equivalent to the total oxygen blown per day in accordance with $C + \frac{1}{2}O_2 = CO$

X = pounds of coke burned at the tuyeres per ton of pig iron produced

In other words, when X pounds of coke have burned at the tuyeres they have been accompanied by enough other materials to make a ton of pig iron. Bear in mind that X is by no means equal to the total coke charged per ton of pig iron, because part of the coke reacts in the stack and part remains in the iron.

The coke burned at the tuyeres per ton of pig iron is the coke equivalent to the oxygen in the blast per day, divided by the tons of pig iron produced per day. This calculation depends on the accuracy of air measurements about which there is some controversy, and it is therefore preferred to use some other method.

The problem is to find a means of calculating the coke burned at the tuyeres per ton of pig iron without making use of the oxygen blown per ton of iron produced. If this can be done the obtained figure can be divided into the coke equivalent to the oxygen blown per day and the quotient, on the basis of the above reasoning, should be a good estimate of production.

In developing the method it is shown that the total coke charged per ton of pig iron can be separated into two portions; viz., the portion which reacts in the stack and the portion which burns at the tuyeres. It involves the solution of two simultaneous equations, based on the chemistry of the charge,which do not involve the volume of blast per ton of product. It will suffice here to quote the two equations.

$$(1) \qquad X + Y = K$$

$$(2) \qquad X + (R+2)\,Y = \frac{F\,(R+1)}{3.11\,D}$$

Where:

X = Coke burned at tuyeres, lb per net ton of pig iron.

Y = Coke reacted in stack, lb per net ton of pig iron.

R = CO/CO_2 ratio (after correction for CO_2 in limestone)

D = Fraction of fixed carbon in coke.

F = Iron reduced from oxides, lb per net ton of pig iron.

K = Pounds of coke remaining after deducting coke to carburize iron and reduce impurities such as Si and Mn.

TABLE I

Operating Data No. 1 Blast Furnace

Hamilton Average for 1945

Air blown	40,520 C.F./M. at 60 F — 30 in. Hg
Air blown	58,348,800 C.F./Day at 60 F — 30 in. Hg
Air blown	55,206,720 C.F./Day at 32 F
Pig iron produced	725 N.T./Day
Coke per ton pig iron	1,504 pounds
CO/CO_2 ratio — observed	2.09
CO/CO_2 — corrected for limestone	2.47
Blast temperature	1,200 F
Top temperature	304 F
H_2O in air	3.8 Grs/C.F.

Materials	Pounds/ton iron
Ore	971
Scrap	221
Scale	322
Sinter	1866
Total metallic	3380
Coke	1504
Limestone	584
Gravel	93
Total burden	5561
CO_2 in limestone	37.01%
CO_2 in gravel	23.48%

Other data used

Specific heat N_2, O_2, CO, Air = 20 Btu/MCF/ F

Heat of combustion:

$C+\frac{1}{2}O_2=CO$	47,500 Btu/ # Mol C
	3,960 Btu/ # C
	132,312 Btu/MCF CO
	264,624 Btu/MCF O-

Analysis of air: 21% O_2, 79% N_2

Heats of reactions

$CO_2+C=2CO$	Consumes 6238 Btu/lb C
$Fe_2O_3+3CO=2Fe+3CO_2$	Generates 136 Btu/lb Fe
$C+\frac{1}{2}O_2=CO$	Generates 3960 Btu/lb C

Average Pig Iron Analysis

Carbon (assumed)	4.00%
Silicon	0.91
Manganese	1.62
Sulphur	0.022
Phosphorus	0.171
Copper	0.027
Total impurities in pig iron	6.75%
Fixed carbon in coke (average at 3% moisture)	88.0%

Table I shows the average operating data for No. 1 furnace for 1945. To apply the two foregoing equations to the operating data first evaluate F and K.

$$F=2000\left(1-\frac{\%\text{ Total impurities}}{100}\right)\frac{\text{Scrap}}{\text{N.T. pig iron}}$$

$$F=2000\left(1-\frac{6.75}{100}\right)-221$$

$F=2000(.9325)-221$

$F=1644$ pounds Fe from ore

$$K=\frac{\text{Coke}}{\text{N.T. pig iron}}-\frac{2000[\%C+(.86)(\%Si)+(.22)(\%Mn)+\text{etc.}]}{100\ D}$$

$$K=1504-\frac{2000[4.00+(.86)(.91)+(.22)(1.62)+\text{Negligible}]}{(100)(.880)}$$

$$K=1504-2000\left(\frac{5.1390}{88.0}\right)$$

$K=1504-117$

$K=1387$ pounds coke

Substituting the necessary data from Table I, along with the values of F and K, into the general equations given above, the following two numerical equations are obtained:

(1) $X+Y=1387$

(2) $X+4.47Y=\frac{(1644)(3.47)}{(3.11)(.880)}=2084$

Solving for X and Y gives:

X = 1186 pounds coke per net ton of pig iron burned at tuyeres by air blast.

Y = 201 pounds coke per net ton of pig iron reacted in stack.

Since each 1186 pounds of coke burned at the tuyeres must have been accompanied by enough other material to make one net ton of pig iron, it should be possible to estimate production by dividing the coke equivalent to the blast per day by 1186. This may be done as follows:

Air blown	=	40,520 cfm (60 F)
Air blown	=	38,338 cfm (32 F)
Air blown	=	55,206,720 cu ft per day 32 F
O_2 blown (21% air)	=	11,593,411 cu ft per day
O_2 blown	=	32,293 lb mols per day
Equiv. carbon	=	64,586 lb mols per day
Equiv. carbon	=	775,032 lb per day
Equiv. coke (Fix. C = 88%)	=	880,718 lb per day

Production should be $=\frac{880,718}{1186}=743$ N.T. pig iron per day.

This is a good check when compared to the actual production of 725 net tons per day shown in Table I.

In order to apply this method to the estimation of production by a considered process, it is necessary to know the difference between the heat required per ton of pig iron by the new process and by the standard process.

The net heat available to a blast furnace after all the reactions involving iron, carbon and oxygen have been satisfied can be stated in general terms very simply. Such a statement is shown below for the standard process and a considered process.

General Statement of Net Heat Available to a Blast Furnace

	Btu/Net ton	
	Standard process	Considered process
Btu generated at tuyeres $C+\frac{1}{2}O_2=CO$	3960 XD	3960 X'D
Btu generated in stack $Fe_2O_3+3CO=2Fe+3CO_2$*	136 F	136 F
Btu consumed in stack $C+CO_2=2CO$	6238 YD	6238 Y'D
Heat received from blast	B	B'

Let H = Net heat available by standard process
and H′ = Net heat available by considered process
Then (1) H = 3960XD + 136 F — 6238YD + B
and (2) H′ = 3960X′D + 136 F — 6238Y′D + B′
*F is the same in either process assuming the same pig iron analysis and same scrap charge. 136 = Btu generated per lb of Fe by $Fe_2O_3 + 3CO = 2Fe + 3CO_2$.

Since the furnace, operating by either process, must balance the heat generated and consumed, it is equally correct to say that the two expressions represent the net heat consumed for other purposes after all reactions involving iron, carbon and oxygen have been satisfied.

Since equals subtracted from equals leave equal remainders these two expressions can be converted to this one:

$$(3)\quad H - H' = 3960\ D\ (X - X') - 6238\ D\ (Y - Y') + (B - B') = E$$

The symbols are interpreted as follows:

X = Lb coke burned at tuyeres per N.T. pig iron in the standard process

X′ = Lb coke burned at tuyeres per N.T. pig iron in the considered process

3960 = Btu generated per lb of C by $C + \frac{1}{2}\ O_2 = CO$

Y = Lb coke reacted in stack per N.T. pig iron in the standard process

Y′ = Lb coke reacted in stack per N.T. pig iron in the considered process

6238 = Btu consumed per lb of C by $C + CO_2 = 2CO$

B = Btu per N.T. pig iron carried into furnace by blast in the standard process

B′ = Btu per N.T. pig iron carried into furnace by blast in the considered process

D = Fraction of fixed carbon in coke

E = Difference in Btu per N.T. pig iron required by the two processes for all other purposes after the reactions involving Fe, C, and O are satisfied.

The value of E in Btu per net ton of pig iron can usually be calculated or at least estimated. If this is done equation (3) above can then be solved simultaneously with two other relations that have been previously worked out.

To summarize at this point, the three relations to be solved simultaneously are as follows:

$$(1)\quad X' + (R+2)Y' = \frac{F(R+1)}{3.11\ D}$$

$$(2)\quad T' = \frac{G'}{X'}$$

$$(3)\quad E = 3960\ D\ (X - X') - 6238\ D\ (Y - Y') + (B - B')$$

These three equations involving X′, Y′, and T′ can now be applied to determine the production and coke consumption of any considered process for which E can be estimated.

Application of equations to a Problem—

Problem — The operating data for No. 1 furnace for 1945 is given in Table I. Taking this as a standard process, estimate the effect of enriching the blast so that it contains 30 per cent O_2. Consider the charge mixture, analysis of the pig iron, blast temperature and CO/CO_2 ratio to be the same for the standard and proposed processes. Adjust the blowing rate using 30 per cent oxygen so that the volume of gas leaving the tuyere zone per minute will be the same as in the standard process.

Solution — Restating the three general equations in terms of the specific example, and using the subscript 30 to designate the degree of enrichment concerned in the example, the expressions become as follows:

$$(1)\quad X_{30} + (R+2)Y_{30} = \frac{F(R+1)}{3.11\ D}$$

$$(2)\quad T_{30} = \frac{G_{30}}{X_{30}}$$

$$(3)\quad E_{30} = 3960\ D(X - X_{30}) - 6238\ D(Y - Y_{30}) + (B - B_{30})$$

The first step is to estimate E_{30}. This is done by compiling Table II of which Item 16, under the 30 per cent O_2 column, is the value of E_{30}.

For ease of tabulation it seemed best to construct Table II in terms of units per minute. Item 16 is then obtained by multiplying item 15 by the number of minutes in a day (1440) and dividing by the unknown tonnage, in this case T_{30}.

Therefore, for 30 per cent O_2 in the blast:

$$E_{30} = \frac{(702{,}577)\ (1440)}{T_{30}} \qquad \text{(Item 16)}$$

It is convenient to obtain E_{30} in terms of X_{30} as follows:

$$G_{30} = 1{,}171{,}060 \qquad \text{(Item 19)}$$

$$\text{Since } T_{30} = \frac{G_{30}}{X_{30}} = \frac{1{,}171{,}060}{X_{30}}$$

$$\text{Therefore } E_{30} = \frac{(702{,}577)\ (1440)\ (X_{30})}{1{,}171{,}060}$$

$$E_{30} = 864\ X_{30}$$

The next step is to evaluate (B — B′) in terms of X_{30} as follows:

Heat in blast for standard process:

$$B = \frac{(38{,}338)\ (1440)\ (.020)\ (1200)}{725}$$

= 1,827,533 Btu per net ton

Heat in blast for 30 per cent O_2 process:

$$B_{30} = \frac{(35{,}683)\ (.020)\ (1200)\ (1440)}{T_{30}}$$

$$= \frac{1{,}233{,}204{,}480}{T_{30}}$$

$$\text{However, as before } T_{30} = \frac{1{,}171{,}060}{X_{30}}$$

Therefore: $B_{30} = \frac{(1{,}233{,}204{,}480)\ (X_{30})}{1{,}180{,}477} = 1045\ X_{30}$

And $(B - B_{30}) = 1{,}827{,}533 - 1045\ X_{30}$

Equation (2) is not needed immediately since it has already been used to evaluate E_{30} and $(B - B_{30})$ in terms of X_{30}.

All the data needed are now available for substitution in equations (1) and (3). It is summarized as follows:

$X = 1186$
$Y = 201$
$R = 2.47 = CO/CO_2$ (Corrected for CO_2 in stone)
$F = 1644$
$D = 0.88$ (1945 analysis allowing 3% moisture)
$E_{30} = 864\ X_{30}$
$(B - B_{30}) = 1{,}827{,}533 - 1045\ X_{30}$
$G_{30} = 1{,}171{,}060$

Substituting the data in general equations (1) and (3), numerical equations are obtained as follows:

(1′) $X_{30} + 4.47\ Y_{30} = \frac{(1644)\ (3.47)}{(3.11)\ (.88)} = 2084$

(1′a) Whence $Y_{30} = \frac{(2084 - X_{30})}{4.47}$

(3′) $3960(.88)\ (1186 - X_{30}) - 6238(.88)\ (201 - Y_{30}) + (1{,}827{,}533 - 1045\ X_{30}) = 864\ X_{30}$

Simplifying (3′)

$4{,}133{,}210 - 3485\ X_{30} - 1{,}103{,}289 + 5489\ Y_{30} + 1{,}827{,}533 = 1909\ X_{30}$

(3′a) $5489\ Y_{30} + 4{,}857{,}454 = 5394\ X_{30}$

Substituting value of Y_{30} from (1′a) into (3′a)

$\frac{(5489)\ (2084 - X_{30})}{4.47} + 4{,}847{,}454 = 5394\ X_{30}$

$(1228)\ (2084 - X_{30}) + 4{,}857{,}454 = 5394\ X_{30}$

$2{,}559{,}152 + 4{,}857{,}454 = 5394\ X_{30} + 1228\ X_{30}$

$6622\ X_{30} = 7{,}416{,}606$

$X_{30} = 1120$ lb coke per net ton at tuyeres

Substitute in (1_a) $Y_{30} = 216$ lb coke per net ton in stack

Substitute in (2) $T_{30} = 1046$ production in net tons per day

Thus the solution indicates that with a blast containing 30 per cent O_2, and no other changes in burden, analysis, CO/CO_2 ratio, etc., the expected pig iron production would be 1046 net tons per day.

The coke consumption can be estimated as follows:

Total coke per net ton $= X_{30} + Y_{30} + 117$
$= 1120 + 216 + 117$
$= 1453$ pounds per net ton of pig iron

TABLE II

CALCULATION OF DIFFERENCE IN HEAT REQUIRED PER NET TON OF PIG IRON DUE TO ENRICHING THE BLAST WITH OXYGEN ESTIMATION OF PRODUCTION AND COKE CONSUMPTION — HOT BLAST 1200°F. COLD BLAST 0°F.

	Item	STANDARD PROCESS	PROCESSES COMPARED TO STANDARD PROCESS	
		Atmospheric Air 21% O_2 Hot Blast	Enriched Air 30% O_2 Hot Blast	Enriched Air 30% O_2 Cold Blast
1	Blowing Rate Measured at 60°F 30" Hg. CF/Min.	40,520	37,714	37,714
2	Blowing Rate Converted to 32°F 30" Hg. (Std. Cond.) CF/Min.	38,338	35,683	35,683
3	Oxygen Blown CF/Min. $(I_2)\ (.21)$	8,051	10,706	10,706
4	Nitrogen Blown CF/Min. $(I_2 - I_3)$	30,287	24,977	24,977
5	CO formed at Tuyeres CF/Min. $(I_3)\ (2)$	16,102	21,412	21,412
6	Total Gas Leaving Tuyere Zone CF/Min.	46,389	46,389	46,389
	HEAT ITEMS IN BTU/MIN.			
7	Generated by $C + \frac{1}{2} O_2 = CO$ BTU $= (I_3)\ (264.624)$	2,130,488	2,833,065	2,833,065
8	Consumed to raise N_2 & CO from 1200°F to 2750°F. BTU $= (I_6)\ (.020)\ (1550)$	1,438,059	1,438,059	
8a	Consumed to raise N_2 & CO from 0°F to 2750°F. BTU $= (I_6)\ (.020)\ (2750)$			2,551,395
9	Total Heat Available After Heating Gases $(I_7 - I_8)$	692,429	1,395,006	281,670
10	Gain in Heat at Tuyeres		+ 702,577	— 410,759
11	Heat in Gas Leaving Tuyeres at 2750°F BTU $= (I_6)\ (.020)\ (2750)$	2,551,395	2,551,395	2,551,395
12	Heat Carried Out by Gases at 304°F BTU $= (I_8)\ (.020)\ (304)$	282,045	282,045	282,045
13	Heat Given to Charge BTU/Min.	2,269,350	2,269,350	2,269,350
14	Heat Gained in Stack BTU/Min.		NONE	NONE
15	Total Heat Saved BTU/Min. $(I_{10} + I_{14})$		+ 702,577	— 410,759
16	Heat Saved Per Ton Pig Iron Produced (Item 15) (1440)/T where T = unknown tons per day		(702,577) (1440)/T	—(410,759) (1440)/T
17	Blowing Rate CF/Day $(I_2)\ (1440)$	55,206,720	51,383,520	51,383,520
18	Oxygen Blown CF/Day	11,593,411	15,415,056	15,415,056
19	Coke Equivalent to O_2 per Day — Pounds 88% Fixed C	880,718	1,171,060	1,171,060
20	Indicated Production Rate NT/Day	743	1,046	664
21	Coke Reaching the Tuyeres Lbs./NT Pig Iron	1,186	1,120	1,763
22	Coke Used in Stack Lbs./NT Pig Iron	201	216	72
23	Coke to Carb. Fe & Reduce Impurities Lbs./NT Pig Iron	117	117	117
24	Indicated Coke Rate Pounds/Net Ton Pig Iron	1,504	1,453	1,952

The 117 pounds of coke added is the amount required to furnish 4 per cent carbon to the pig iron and reduce silicon and manganese.

Calculations for cold blast—

Item 16 in column three of Table II provides the value of E_{30} for operating on cold blast using 30 per cent oxygen.

$$E_{30} = -\frac{(410{,}759)\ (1440)}{T_{30}}$$

Note that in the case of cold blast, even with 30 per cent oxygen, there is less heat available per minute than by the standard process using a hot blast temperature of 1200 F.

Using the data from column three and solving the three equations as before, the results obtained are as follows:

X_{30} = 1763 lb coke per net ton at tuyeres
Y_{30} = 72 lb coke per net ton in stack
T_{30} = 664 production in net tons per day
Total coke rate per net ton = 1952

Some advocates of oxygen enrichment of the blast have suggested that stoves would not be needed. However, this calculation indicates plainly that enrichment will have to exceed 30 per cent oxygen before the increased oxygen will compensate for hot blast.

The method presented here provides a means of estimating production and coke consumption for various modes of operation by comparing them to a selected standard period of actual operations.

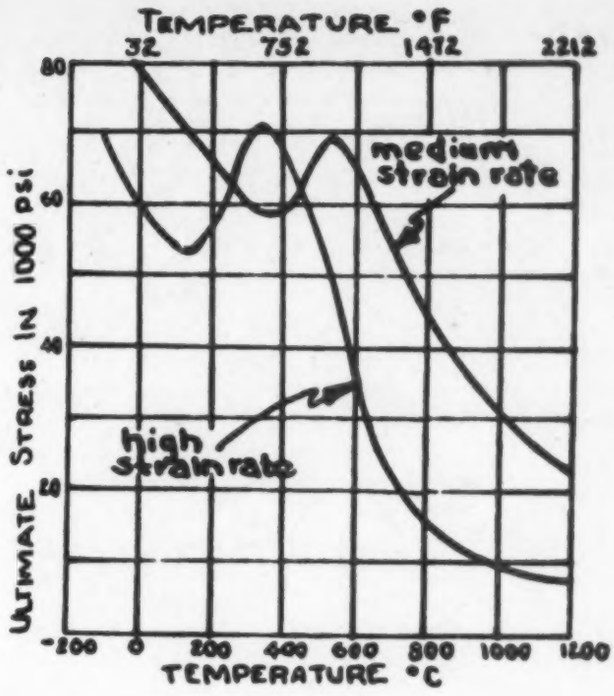


Figure 1 — Relationship between resistance of steel to deformation and temperature.

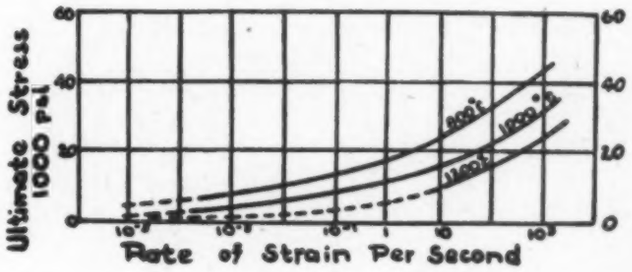
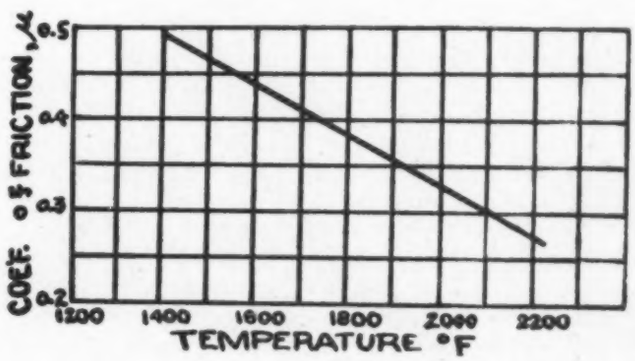


Figure 2 — Relationship between resistance of steel to deformation and strain rate.

▲

Figure 3 — This chart, compiled from conflicting data, attempts to show the relationship of friction and temperature in steel.



SHAPING AND FORMING

By WILLIBALD TRINKS, Professor Emeritus, Carnegie Institute of Technology, Pittsburgh, Pennsylvania

▲ IN the study of plastic deformation of crystalline bodies, such as metals, we encounter a deep cleavage between hot-forming and cold-forming. When used in this connection, the terms hot and cold are ambiguous and misleading, because, for a number of metals, deformation at room temperature is hot forming. Lead is such a metal. The true dividing point between cold-working and hot-working is the critical temperature above which a deformed metal recrystallizes, and below which deformed crystals retain their shapes. Different metals have not only different recrystallization temperatures, but they also have different recrystallization speeds. Iron and steel recrystallize so rapidly that steel tubes, 40 feet long, can be extruded in 2½ seconds. On the other end of the line, certain aluminum alloys recrystallize so slowly that tubes made from these alloys barely crawl out of the extrusion press. A higher speed causes the expected tube to come out in short pieces.

In hot working, that is to say in mechanical deformation above the critical temperature, the following law is sometimes overlooked. As long as the metal is sub-

jected to so high a compression from all sides that tension cannot occur anywhere, the amount of deformation which the metal can undergo without injury is unlimited. This statement means that an object may be deformed from one shape to a very different shape and that, at the end of the deformation, the material is just as good as new, or even better. If, however, tension appears anywhere in the plastic body, then the deformation is limited by the properties of the material.

Very clean low-carbon steel can withstand an enormous elongation by tension; it behaves like taffy. Commercial steels contain oxides, sulfides, phosphides, absorbed gases, and particles of refractory material. The greater the content of impurities, the smaller is the safe elongation by tension.

EXAMPLES OF TENSION IN COMPRESSION

In everyday compression processes, such as rolling or forging, tension occurs in unsuspected places. The greater the angle of contact or the "nip," the more severe are the pulling and pushing stresses. Very dirty steels show tension cracks with contact angles as low as 20 degrees. Roll designers have formulated the rule that even good commercial steels show surface cracks if the contact angle exceeds 32 degrees, unless the linear rolling speed is extremely low. It is understood that large contact angles require artificial roughening of the rolls.

PIERCING OF METAL

The piercing of metal by cross rolling over a piercing point is probably the most outstanding example of producing severe tension in a compression process. Stiefel, the dean of tube mill engineers in the United States, used to say that owners of boilers buy seamless tubes, because the existence of a seamless tube is an unfailing proof of clean, sound steel.

The force which is required to deform a metal above its critical temperature is, above all, a function of the temperature of the metal; it drops to zero at the melting temperature. The relation between resistance to deformation and temperature is not a straight-line function. For steel, it is a complicated curve, as can be seen from Figure 1.

The illustration reveals another fact, namely that temperature is not the only variable which affects resistance to deformation. Viscosity, also called internal friction, plays a very important part. The effect of viscosity is that the resistance to deformation is a function of the rate of deformation, which latter is also known as strain rate. If a block is compressed to half its original height, the specific deformation or unit deformation is distance of compression divided by original height, or in this case one half, which is a ratio or dimensionless number. If the act of compression requires one quarter second, then the compression rate or strain rate equals one-half divided by one-quarter, which equals two. The dimension is one over seconds, or seconds to the minus one. The relation between resistance to deformation and strain rate is shown in Figure 2.

Hot metals, kept at a constant temperature, can be deformed by least pressure and with least work if the unit deformation takes place very slowly. In carrying out this doctrine, we run into a dilemma. In commercial shaping and forming, it is not practical to keep the temperature constant. Slow deformation affords time for cooling of the hot metal, with the result that the resistance to deformation grows while deformation goes on.

In seeking the optimum compromise between low resistance due to slow deformation and low resistance due to high temperature, we run into the old battle between the squares and the cubes. Large ingots can be, and are deformed slowly, because their masses are so great in comparison with their heat dissipating surfaces, that we can take advantage of the reduction of force which goes with slow deformation. At the other end of the line, thin objects, such as wire and hot strip, are deformed at high speed, just as rapidly as handling facilities permit, because slow deformation would soon result in cold-forming of the thin objects.

Besides keeping the metal from cooling, rapid deformation offers an additional advantage. The deformation resistance becomes so great that the deformed material is heated by the great internal friction, whereby cooling by radiation and by contact with the cold tools is partly, and, in some cases wholly, counteracted. This counterplay of cooling and heating is the reason why, in practice, the deformation resistance does not rise as rapidly with strain rate as laboratory tests would indicate.

If there is a lesson to be learned it is this: Each particle of a plastic mass always moves in the direction of least resistance. Mathematical science has been able to foretell that direction in a few very simple cases only. In almost all practical cases, conditions are so complicated that the man in the forge shop or in the rolling mill must use his judgment, which is based upon experience, in order to foretell the direction of flow.

One of the decisively determining influences in shaping and forming is friction of the plastic material, both upon itself and on the forming tools. The latter friction depends upon several factors, such as composition of the plastic material, temperature of the plastic material, composition and roughness of the forming tool, and upon lubrication between the surfaces.

Truly reliable data on the friction between hot steel and cold steel or iron are not available. Figure 3 was drawn by the author from a compilation of more or less conflicting data.

The reduction of friction coefficient of steel by increase of temperature has been tentatively explained by the softening and melting of the sulphides and of the phosphides. If this explanation is correct, then high-sulphur steel must slip and skid more easily in the rolling mill than other steels do. Operators know that it does. The higher phosphorus content of bessemer steel may be the reason why that steel spreads differently in the rolling mill than open hearth steel does.

Making the working rolls extra hard raises their elastic limit, but does not reduce the roll flattening. The latter is a function of the modulus of elasticity, which is the same for soft steel and for hard steel. Tungsten carbide, often alloyed with other carbides, has been used as roll material in small mills. On account of the high modulus of elasticity, roll flattening is much re-

duced. In addition, the very smooth finish which carbide rolls can be given reduces the friction. The combined result is a very low roll pressure and a small separating force.

In cold rolling, friction can be the cause of building up roll pressures which are great enough to spall even the best rolls. It seems queer, because we can shoot plenty of lubricant into the wedge-shaped opening between the strip and the roll. But, if that lubricant be a straight mineral oil, it is squeezed out by the high pressure. And in those parts of the contact region, where the oil has been squeezed out, dry friction prevails. To prevent this happening, the oil must be blended with a polarized or extreme pressure lubricant, such as, for instance, palm oil. Such lubricants have an affinity for steel and offer great resistance to being squeezed out. They are, however, not entirely squeeze-proof, which fact can be judged from the following experience. Strip is thicker near the ends of the coil than in the center. During acceleration at the beginning, and during retardation at the end of rolling a coil, the rolling speed is smaller than it is in the rest of the time. In consequence, more time is available for squeezing out the lubricant, skin friction grows, the rolls flatten more, and a higher roll pressure would be needed to produce the same reduction as is obtained at higher speed.

Care is needed in the selection of an extreme pressure lubricant, if it is to lubricate a strip which serves for making tin plate. All extreme pressure lubricants contain a radical which has chemical affinity for the material being rolled. For that reason they resist being wiped off or squeezed out. But it is important that the radical is not so strong that its affinity to the strip prevents its being thoroughly removed before tinning. The better the extreme pressure lubricant solely for lubrication purposes is, the greater is the danger of having some of it stick to the strip, whereby wasters would be produced in the tinning machine.

FINISHING STEEL FOR DECORATIVE AND PROTECTIVE PURPOSES

By REID L. KENYON, Associate Director, Research Laboratories, The American Rolling Mill Company, Middletown, Ohio

▲ THE wide adaption of flat-rolled steel products to the many applications in which they are now used might not have been possible without adequate surface treatment. Some surface coating is generally required to protect ferrous metals from corrosion, and efforts to provide such protection have also included enhancement of surface beauty. The five main types of surface finishes include: (1) the nonmetallic finishes, such as paint and lacquer; (2) the metallic coatings, such as electroplated chromium, nickel, and copper, and hot-dipped coatings, such as tin, terne, galvanized and aluminized; (3) a combination of metallic coatings with special treatments to receive nonmetallic coatings; (4) porcelain enamel; and (5) stainless steel and its special finishes. Improved metals and finishes have permitted the application of thinner coatings at reduced costs and with greater shock resistance imparted. Such progress as this helps to account for the fact that in 1945 and 1946, shipments of sheet, strip and tin plate increased twice as much over 1920 as total finished steel shipments.

THE SELECTION AND APPLICATION OF STATISTICAL METHODS TO STEEL PLANT PROCESSING PROBLEMS

By E. L. ROBINSON and L. G. EKHOLM, Metallurgical Department, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania

▲ THE greatest obstacle to overcome in realizing the full advantage of the use of statistics in solving industrial problems is undoubtedly the feeling which exists that this is a new and untried method. It will perhaps lessen the strangeness to consider that any number or any figure ascribed to a processing function is a statistic, and as soon as this figure is added to, multiplied by, or divided by another number, it has been subjected to a statistical method.

Let us take a typical problem. In a certain open hearth shop, No. 7 and No. 11 open hearth furnaces were rebuilt, each with checkers of a different design than those used in the other furnaces of the shop. The problem is to determine whether the checker designs of No. 7 and No. 11 furnaces, designated "A" and "B," are better than, worse than, or just as good as the regular checker design (designated "R"), particularly as regards the time of heat from melt to tap, usually designated as "working time." It is well recognized that the working time and the carbon level at which the heat is tapped are closely related to each other, so let us be careful to select only those heats made to the same specification, in this case 0.07 per cent carbon. This precaution should eliminate much of the variation in working time, and so we should not require an unduly large number of heats in order to determine the actual difference between furnaces.

Let us try comparing the average value for five heats from each furnace against the shop average. The shop average is based on 151 heats, all made to a 0.07 per cent carbon specification and selected at random from furnaces other than the No. 7 and No. 11 furnaces under study, giving an average working time for the shop of 2.92 hours. Thus, based on the average of five heats from each of the experimental furnaces, the data show that No. 7 furnace with "A" type checkers gave something more than a half hour better performance than the shop average, whereas No. 11 furnace, with "B" type checkers, showed a working time performance

TABLE I

Comparison of Average Working Times of Two Furnaces with the Shop Average

Furnace number	7	11	All others
Type of checkers	"A"	"B"	"R"
Total number of heats	5	5	151
Average working time (hours)	2.28	3.48	2.92
Difference from shop average (hours)	−0.64	+0.56	.....

a half hour slower than the average, as shown in Table I.

The result is pleasing; let us try the new design on a

larger group of furnaces. But wait. The conclusions reached may be completely incorrect; any operator or

TABLE II

Tabulation of Average Feed Ore, Melt Carbon and Working Time Values

Furnace number	7	11	Shop
Average working time (hours)	1.98	2.70	2.92
Average melt carbon (per cent)	0.61	0.83	0.87
Average ore feed (lb per 1000 lb melt)	10.9	19.4	15.9
Number of heats	33	24	151
Total feed ore per heat (lb)	2020	3250	2890

metallurgist who took the time to glance at the data shown in Table II which data became available after 33 heats were tapped would notice immediately that the 33 heats from No. 7 furnace melted at an average of 0.61 per cent carbon and consumed an average of 2021 lb of feed ore as against an average of 0.87 per cent carbon and 2890 lb of feed ore for the shop. Further investigation is necessary.

By manipulation of feed ore and melt carbon curves by multiple correlation, the quantitative effects of these two variables on working time can be determined with a fair degree of accuracy. The working time of No. 7 furnace can now be adjusted to what it would have been if the melt carbon and the feed ore values for this furnace had been the same as the shop average values. The corrected curves show that for each increase of one point in melt carbon the working time increased 0.0225 hours; likewise for each pound increase in feed ore (per 1000 lb of metallics charged) the working time decreased 0.014 hours. No. 7 furnace had an average of 26 points less carbon at melt and 5 pounds less feed ore than the respective averages for the shop. Using these factors, it is found that the average working time of No. 7 furnace would have been 2.48 hours if the heats in this furnace had melted at the same carbon level and required the same amount of feed ore as the heats from the remainder of the shop.

The test of significance then shows that although the adjusted average for working time is closer to the shop average than was the unadjusted average and the saving effected by the change in the checkers is not as great as was at first thought (only 0.4 hours), the saving in time is still significant. The test of significance does not tell why the furnace is better, it merely states that the averages are in fact significantly different.

BLAST FURNACE BELL DEVELOPMENT

By TRUMAN H. KENNEDY, Assistant General Superintendent, National Tube Company, McKeesport, Pennsylvania

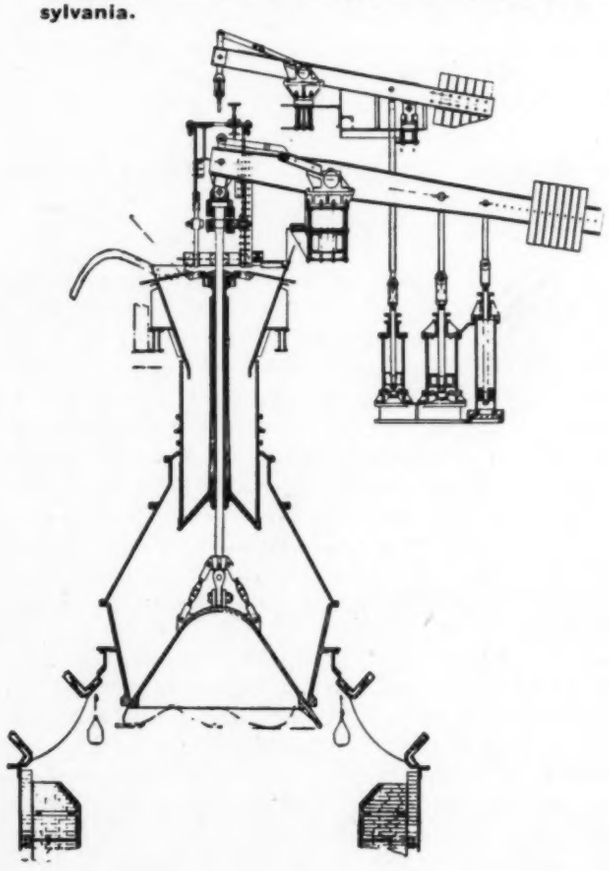
▲ IT HAS been a recognized fact since early in the history of the blast furnace in its present form that the method of charging was one of the most important factors affecting the economy of furnace operation. As they have been for nearly a hundred years, blast furnaces are still charged in a fashion which deposits the ore in an annular ring bounded on the outside circumference by the inside wall of the furnace. Inside this annular ring there usually occurs a relatively ore-free center of coke, the diameter of which is controllable by various means at the disposal of the operator.

Correct distribution should not only aim toward the placement of ore in position to properly proportion the flow of gas between the ore covered annulus and the open center, but should also aim to avoid the establishment of areas impervious to gas currents. This latter may best be accomplished by wider distribution of fines throughout the entire ore layer.

It is obvious that the most desirable means of maintaining a proper gas flow distribution would be to widen the ore annulus, if it can be accomplished without the creation of excessively thick ore layers or without the sacrifice of the customary dense area adjacent to the walls. Such a change should extend the limits of the controls which have been exercised so effectively on furnaces of smaller top dimensions. It is believed that the first actual installation of apparatus designed for this purpose is that of the serrated bell installed on National Tube Company's No. 1 blast furnace at McKeesport, Pennsylvania, in June, 1944. This bell (National Tube Company patent No. 2306811) is in all respects similar to the conventional bell except for the serrated section below the hopper seat and the mechanism for radial movement which is attached to the top of the bell rod.

Since this was the initial installation, the dimensions of the bell and its relationship to other components are the result of study rather than experience. No changes were made in the original 19 ft throat diameter on this first installation. There are six radial serrations of 10½

Figure 1 — This serrated bell is in use on National Tube Company's No. 1 blast furnace at McKeesport, Pennsylvania.



in. horizontal depth at 60 degree intervals around the edge of the bell. Bell diameter is 14 ft across the crest of the serrations, and 12 ft 3½ in. at the trough of the serrations.

It is designed for 10 degree radial movement on each closing stroke of the bell or 60 degrees from crest to crest in six successive dumps of the bell, thus forming a series of serpentine or sinuous ridges adjacent to the furnace wall. It is interesting to note that because of velocity gained in sliding over the long overhang, the depth of the serration in the ore ridge is approximately double that of the bell.

Since the fines of the charge tend to segregate along the crest of these ridges, they are thereby distributed over the much wider area bounded by the furnace wall and the trough of the serrations in the ore ridge. The average area of the ore-free center is also reduced in relation to the total area.

The bell is supported by a swivel head which encloses a roller thrust bearing upon which the "T" shaped head of the bell rod turns. Radial movement is effected by a ratchet with an attached cam which travels in an oblique slot.

This mechanism has rendered satisfactory service for almost three years. By comparison with other furnaces of equal size in the same plant, and operating on similar burdens the performance has been very encouraging. The furnace has consistently demonstrated ability to take more wind per square foot of hearth than the other furnaces. Flue dust losses, good product yields and coke consumption compared exceedingly well with other furnaces of approximately the same size.

THE WORLD SITUATION ON COATING MATERIALS, LEAD, ZINC, AND TIN

By C. A. ILGENFRITZ, Vice President, Purchases, United States Steel Corporation, Pittsburgh, Pennsylvania

▲ PROTECTIVE coatings can be generally classified into three categories. One group is recognized as organic, such as paints, lacquers, oils and waxes; a second is inorganic, such as cement or clay; and the third is metallic. This discussion concerns three of the principal metals widely used for coating to preserve other metals. These are lead, zinc and tin.

Lead ore occurs in various parts of the world. The principal producing countries are the United States, Canada, Mexico, Australia, Germany, and Burma. It is reported that the United States has approximately 14 per cent of the world's lead-ore reserves which, it is estimated, will last only 12 years based on the 1935-1939 annual rate of consumption.

Refinery capacity at the close of 1940 was 2,200,000 net tons outside and 1,068,000 net tons inside the United States. Five years later capacity here had dropped to 975,000 net tons, with Missouri alone accounting for about 24 per cent. Since 1939, there has been very little new plant construction here, while some of the foreign producing units suffered heavily during the war. This was especially true of the famous Baldwin zinc-lead mine and smelter in Burma, which had produced 75,000 tons of lead per year before the war.

The United States is credited with approximately 19 per cent of the world's zinc-ore reserves. It is estimated these reserves will last 19 years at the 1935 to 1939 annual rate of consumption. As with lead, the United States is the world's largest producer of zinc and also is the largest consumer.

Zinc supplies are tight and probably will continue scarce as long as domestic consumption stays at the existing high level and until production in foreign countries picks up. Lack of fuel is holding production in Belgium to about 75 per cent and in France and Norway to about 50 per cent. Higher prices abroad are attracting zinc from Mexico which normally is shipped to American users.

The United States is not a producer of tin ore. Aside from an earlier period when two smelting plants were operated for a short time on foreign ore, one in New Jersey and one in Long Island, it has only been since 1942 that we smelted tin in this country. A government-financed plant began operation five years ago at Texas City, Texas, operating entirely on ore from foreign countries, mostly from Bolivia. The production of this smelter, which began operating and turned out 15,695 tons in 1942, was 43,648 tons last year.

World tin production is improving, but progress will be slow. The 1947 output is estimated at 50 per cent of the prewar rate and, while 1948 should show continued improvement, full production is not expected before 1949. Meanwhile, it probably will be necessary to continue some restrictions on tin uses to insure supplies for the more essential needs.

Tin is one of the more important coating materials. Most of the world's production of this primary metal is used for that purpose. The coating is applied by either of two methods, the hot dip or the electrolytic process. The trend is strongly upward in the production of electrolytic tin plate in the United States. Last year about 36 per cent of the tin plate produced here was by the electrolytic process and 64 per cent was hot dipped. A projected estimate indicates that by 1950, electrolytic tinning may increase to about 66 per cent with hot dipped dropping to about 34 per cent of the total coated products made. Tin is also used in the manufacture of solder, babbitt, bronze, collapsible tubes, and a number of other important commodities.

Before the war, United States manufacturers used 39 per cent of the world's total production of primary tin, and of this amount about 53 per cent was for protective coatings. On a non-restrictive basis, it is estimated tin users here will require 85,000 gross tons while world requirement will be 195,000 gross tons of primary tin annually.

Stocks in the United States held by private industry and the government declined approximately 14,000 tons during 1946. There will be a further decline this year. Even if controls are continued, indications are that government reserve stocks, exclusive of those held for permanent stockpiling, will be exhausted by the end of 1947. It is anticipated that world stocks will reach a low of about 40,000 tons by January 1, 1948. There will be a slight improvement during that year and the stock on January 1, 1949, should be about 48,000 tons. It will probably be a year later than that before we have a good world-wide supply.

PROBLEMS INVOLVED IN FABRICATION OF HIGH TEMPERATURE ALLOYS

By GUNTHER MOHLING, Associate Director of Research, Allegheny Ludlum Steel Corporation, Watervliet, New York

▲ THE fabrication of high temperature alloys for use in gas turbines and jet engines for aircraft require alloys which are designed to operate at maximum strength and stability in the range of 1200 to 1500 F. These have as their principal constituents chromium, nickel, cobalt, molybdenum, tungsten and columbium.

In order to insure proper performance the alloys are tested under stress for 1000 hours at various temperatures within the expected working range. Some of the materials tested have gone 26,000 hours without change in vital characteristics. Rolling and forging these high temperature alloys present some difficulties over conventional steels but closer control of temperatures, the use of artificial atmospheres and longer than normal heating cycles have solved most of the problems.

THE MINERALOGY OF BASIC OPEN HEARTH SLAGS

By J. L. MAUTHE, Vice President, and K. L. FETTERS, Special Metallurgist, The Youngstown Sheet and Tube Company, Youngstown, Ohio

▲ IN THE making of steel by the basic open hearth process, some form of slag control is recognized as essential to the production of quality steels at economic rates. Open hearth slag is a necessary "evil" with which the industry must contend from the time of charging fluxes into the furnace until it has at last been disposed of on a slag dump, so it is important that the best possible use be made of minimum quantities of slag. Pig iron and scrap, the predominant raw materials for producing steel, contain carbon, silicon, manganese, phosphorus, and sulphur, as well as other alloying elements, all of which must be removed to the lowest possible value or controlled within rather narrow limits. Basic slags high in lime offer the only now known economic means of such control for the basic process, and indeed this process was developed primarily because it offered the only practicable means for the required elimination of phosphorus.

The evolution of modern slag control practices first determined that certain ranges of slag FeO were associated with satisfactory quality, and those heats with FeO outside those ranges were more likely to produce a defective product or at least one that necessitated higher conditioning costs in further mill operations. Correlation studies further indicated a relation between the balance of silica and lime in the charge and the FeO in the slag, practices were evolved where the lime charge was estimated on the basis of the silicon in the iron, and other materials charged or added during the working of the heat. Lime charges were reduced materially and occasionally heats were tapped on the "acid" side with resultant high phosphorus, sometimes with serious attack of the furnace banks or bottoms.

Chemical analyses of slags are time consuming and in most cases the heat will have been tapped before proper adjustments can be made based on such analyses. Slag "pats" poured into a mold, or onto a plate, solidify with an appearance that is characteristic of the minerals which they contain, and since these minerals are closely related to the composition of the slag, the estimation of slag composition from such samples has become the basis for routine control methods in many plants. With such control the desired additions can be made as soon as there is evidence they will be required, resulting in marked improvement in steel quality.

In order to produce steel to present day quality requirements, in an amount somewhere near the demands and at costs that will enable the producer to compete in the industry, slag control has become a vital part of the practices of every open hearth shop.

IRON ORE SUPPLY FOR THE FUTURE

By GEORGE W. HEWITT, Assistant Vice President Operations, Wheeling Steel Corporation, Wheeling, West Virginia

▲ THE long range view of the future of the steel industry tells us that the Lake Superior deposits of iron ore with our unequaled upper and lower lake dock and lake transportation equipment are our great asset and must be preserved for many years to come as the base of our national position and strength. However, the high-grade ore deposits of the Lake Superior area will be exhausted according to estimates within 20-25 years, based upon probable annual requirements of from 60-70 million tons of iron ore from that area. Average normal yearly consumption of iron ore from all areas should be around 90 million tons. Some increased shipments of iron ore from the northeastern States, South America, Canada and Labrador, will slightly ease the demands upon the Lake Superior district over the next few years. But to maintain steel industry operations and preserve our Lake Superior deposits, it will be necessary to recover the extensive low-grade iron ore deposits of

TABLE I

Principal Reserves of Iron Ore in the United States — Estimated Merchantable Ore and Ore that can be Beneficiated by Present Methods — End 1945 (Million Gross Tons)

	State Tax commissions		Engineer's estimate
Minnesota 4-1-1946	1,026		1,355
Michigan 1-1-1946	132		201
Wisconsin 1-1-1946	6		9
Total Lake Superior States	1,164		1,565
	Minimum		Maximum
Alabama	1,000		1,400
Ga.-Tenn.-Ky.-N.C.-Va.-W.Va.	100		500
Total South Eastern States (Commercial)	1,100		1,900
New York		900	
New Jersey		600	
Pennsylvania		100	
Total North Eastern States (Concentrates)		1,600	
Utah		150	
California		75	
Col.-N.M.-Nev.-Mont.-Wash.-Oregon		50	
Wyoming		25	
Total Western States		300	
Texas		140	
Missouri		70	
Other Gulf States		20	
Total South Western States		230	
Total United States	4,394	to	5,595

TABLE II

U. S. Lake Superior Iron Ores Estimated Taxable Reserves — State Tax Commissions — End 1945 (Million Gross Tons) and — Comparison with Mining Engineer's Estimate of Reserves

	Mesabi	Marq.	Menom.	Gog.	Verm.	Cuy.	Total old range	Total
Open pit — direct	465.0	....	....	....	....	11.7	11.7	476.7
Open pit — concentrate	95.9	....	....	....	....	8.1	8.1	104.0
Open pit — stockpile	10.4	....	....	....	....	....	....	10.4
Open pit — total	571.4	....	....	....	....	19.8	19.8	591.1
Underground — direct	330.8	51.6	48.3	37.8	11.5	38.0	187.2	518.0
Underground — concentrate	52.7	....	....	....	....	1.7	1.7	54.4
Underground — stockpile	....	....	....	....	.3	.2	.5	.5
Underground — total	383.5	51.6	48.3	37.8	11.9	39.8	189.4	572.9
Total — all	954.9	51.6	48.3	37.8	11.9	59.6	209.2	1164.1
Mining Engineer's Estimate								
Open pit — total	1094.4	....	....	3.5	....	69.6	73.1	1167.5
Per cent over est tax reserves	92%	....	....	....	....	252%	269%	97%
Underground — total	161.7	96.8	69.5	42.6	25.4	19.1	253.4	415.1
Per cent over est tax reserves	(58%)*	88%	44%	13%	113%	(52%)*	34%	(38%)*
Total — all	1256.1	96.8	69.5	46.1	25.4	88.7	326.5	1582.6
Per cent over est tax reserves	32%	88%	44%	22%	113%	49%	56%	36%

* (Under)

that area with the aid of new concentrating plants to beneficiate the ore and make it usable in the blast furnaces. Several large projects of this type are already underway, and eventually extensive capital investments will be required to build up the production of concentrates to adequate levels.

TRENDS IN METALLURGICAL RESEARCH

By CYRIL STANLEY SMITH, Director, Institute for the Study of Metals, University of Chicago, Chicago, Illinois

▲ THE real frontier in metals, the place where radically new steps will be taken, where really new materials will appear, is physics. Until recently the metallurgist knew so much more about the actual behavior of his metals and alloys that there was little to be gained by discussion with the physicist. We have now reached the point where the theorist can help the practical man. Despite this, there are not more than three univerisities in this country where metallurgical training is given with sufficient emphasis on fundamentals to enable graduates to use fully further discoveries in the theory of physics, and there is no place where physics students are exposed to metallurgical problems. To prove a favorable environment for research in the boundary fields between metallurgy, physics and chemistry, the Institute for the Study of Metals was formed last year at the University of Chicago. The national economy dictates an expansion of the support of fundamental research, and increased amounts of tax income may be diverted to this and the associated training of scientists, unless industrial leaders are willing to support it on a larger scale. Those concerned with the future of metal-producing industries should pay as much attention to the insurance of new developments in the science of metals as to the insurance of continued supply of other raw materials.

AN APPRAISAL OF HARDENABILITY BAND SPECIFICATIONS FOR ALLOY STEEL

By DON RUHNKE, Chief Metallurgist, Republic Steel Corporation, Massillon, Ohio

▲ THE study of cooling rates and the use of the end-quench hardenability tests are resolving the selection of alloy steel into more of a science and less of an art based on experience. Selection of alloy steel is being made for a given application by use of data which correlates hardness values at specific points on the end-quench test with positions on the surface or below the surface of simple sections. The end-quench test is based upon the principle that if heat is extracted rapidly by means of water at 70 F from one end of a one-inch round test bar, different rates of cooling will prevail along the length of the bar and consequently different hardness values will be attained. The distance at which various hardness values occur can be correlated with conditions secured in round bars of various section sizes, and so a correlation with service conditions is attained.

Specification of steel to hardenability limits rather than to chemical composition limits will give the consumer steel which will be more closely controlled for heat treatment purposes. In one case, experience with 306 heats of 8620 H composition had resulted in narrowing the specification limits to about 70 per cent of what might be expected of a like steel ordered to chemical limits. Such narrow limits result in more closely controlled heat treatment procedures in the customers' plants, more uniform mechanical properties in the parts treated, less rejections for failure to meet specifications and less retreating to salvage rejected parts.

FUSETRONS

Hold Harmless Overloads–
Prevent Needless Shutdowns

Many Companies Have Proven It...

For Example–

"Formerly we were troubled by two kinds of needless fuse blowings in our milling machine department. Frequently the operators take too deep a cut in the material on which they are working, building up a momentary overload. Ordinary fuses blew so frequently on this type of overload that it was necessary to install oversize fuses, robbing the circuit of proper protection.

"Our other difficulty came when several machines would start operating simultaneously after rest periods or the lunch hour, blowing the fuses in the main switch, thus shutting down all the machines of the department.

"In June, 1945, Mr. Edward Lambert, our Chief Electrician, solved both difficulties by installing 20 ampere 250 volt Fusetrons in the 30 ampere switches on the individual machines and 200 ampere 250 volt Fusetrons in the main switch. He reports that no outages have occurred since that was done."

Lloyd B. Benham, V. P.
PORTER CABLE MACHINE CO.
Syracuse, New York

BUSS

Keep Electrical Equipment Operating Without Sacrificing Protection

Chart shows 30 ampere 250 volt fuses. Other sizes and 600 volt ratings show similar results.

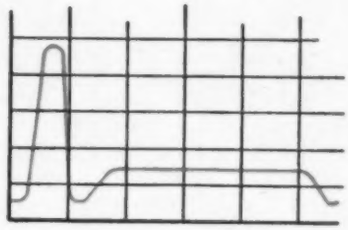
Buss Fusetrons have tremendous time-lag. They *can* hold harmless overloads, yet provide protection against dangerous overloads or short-circuits because they combine a fuse with a thermal cutout.

Here's how the time-lag of Fusetrons compares with that of ordinary fuses:

It is readily seen from this chart why Fusetrons hold harmless overloads and keep circuits operating instead of opening and causing useless shutdowns. Ordinary fuses and other protective devices cannot do this job.

Here's how Fusetron time-lag will work for you. AC motors require a current of 3 to 9 times their rating for starting. This surge of current often causes ordinary fuses to open.

Fusetrons have the capacity to absorb this high starting current without opening, even when the type of load causes starting current to hang on for limited periods.



In normal operation overloads often occur that are heavy but short lived—or light overloads hang on. In either instance they are harmless—yet they may cause ordinary fuses to open.

Fusetrons hold such harmless overloads—and keep circuits in operation.

Fusetrons Also Prevent Needless Blows on Mains and Feeder Circuits

Even when all motors on a circuit start at one time, Fusetrons will not open. For example: four 15 ampere motors on a circuit would ordinarily be protected by 90 ampere fuses. If these 4 motors start at one time the combined starting current is approximately 360 amperes. At this load a 90 ampere fuse would open in about 3 seconds—before the motors could start—BUT A 90 AMPERE FUSETRON WILL HOLD 24 SECONDS, ample time for all motors to start.

So, with Fusetrons installed in the mains, feeders and all branch circuits, shutdowns caused by needless opening of fuses or other forms of protective devices on harmless overloads are entirely wiped out.

Fusetrons Give Many Other Kinds of Protection Heretofore Not Available

What is a FUSETRON?

The Fusetron is a DUAL element device—a Fuse to which is added a Thermal cutout.

The result is a fuse with tremendous time-lag and much less electrical resistance.

Fusetrons have the same degree of Underwriters' Laboratory approval for both motor-running and circuit protection as the most expensive devices made.

Made to the same dimensions as ordinary fuses, Fusetrons fit all standard fuse holders.

Obtainable in all sizes from 1/10 to 600 ampere in both 250 and 600 volt types. Also in tamper-resisting type (Fustats) for 125 volt circuits.

Their cost is surprisingly low.

Fusetrons do everything fuses do, as is confirmed by the Underwriters' Laboratories' Label, and in addition...

★ Provide simplest way to stop burnouts from single phasing. ★ Make burnout protection of SMALL motors simple and inexpensive. ★ Give thermal protection to panelboards and switches. ★ Prevent needless blows caused by heating in panels and switches. ★ Permit use of larger motor or adding more motors on circuit without installing larger switch or panel. ★ On new installations, proper size switches and panels can be used instead of oversize. ★ Protect motors against burnout. ★ Give double burnout protection to large motors. ★ Protect coils, transformers and solenoids against burnout.

Get All The Facts—Get Better Protection Send The Coupon Now

Only one shutdown, or one lost motor or one destroyed panel may cost you far more than replacing every fuse with a Fusetron.

Don't risk such losses—protect your production schedules by changing your entire electrical system to FUSETRONS.

BUSSMANN MFG. COMPANY, University at Jefferson St. Louis 7, Mo.
(*Division McGraw Electric Co.*)

FUSETRONS

SOLD THROUGH WHOLESALERS

BUSSMANN MFG. CO., University at Jefferson St. Louis 7, Mo. (Division McGraw Electric Co.)

Please send me complete facts about BUSS Fusetrons.

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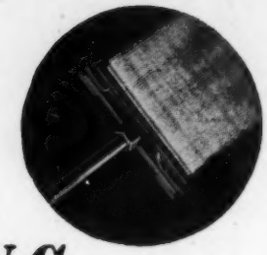
Title_____

Company_____

Address_____

City_____ State_____ 747



FLAME-PRIMING smooths

Flame-priming is a fast, easy, inexpensive way to prepare any metal surface for a smooth, lasting paint coat.

LINDE OXYGEN • UNION CARBIDE
PREST-O-LITE ACETYLENE • OXWELD,
PUROX, PREST-O-WELD, HELIARC,
UNIONMELT EQUIPMENT FOR WELDING,
CUTTING, AND HEATING

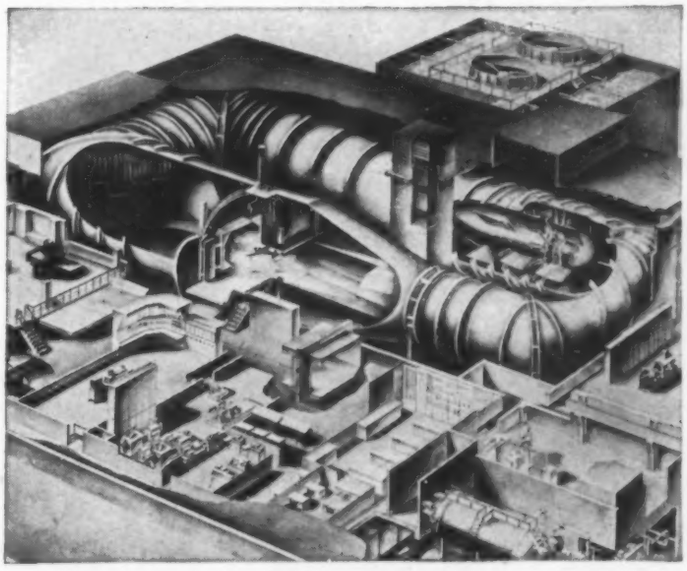
the way for the "Big Blow"

A typhoon is just a puff compared with the wind that whips through this test tube for model airplanes at Cornell Aeronautical Laboratory, Buffalo, N. Y. The "big blow" is created by two 22-foot diameter fans that can generate a wind of over 700 miles per hour.

The inside walls must be smooth, scale free, since this gargantuan blast would shear off any little specks and drive them through a valuable test model plane with devastating force. To prevent this, every little bit of scale was removed from the thousands of square feet of metal surface before painting by Linde's flame-priming process.

Flame-priming is simple to do, requires little equipment, and costs little. A brush of oxy-acetylene flames pops off scale and drives out moisture. Paint applied to the warm, dehydrated surface spreads easily, goes on smoothly, bonds tightly, and lasts longer.

Linde service engineers are always available to help with problems of treating, cutting, joining, and forming metals. Linde research is constantly at work on the development of new and better methods for the production and fabrication of metals.



Two huge 22-foot diameter fans, fabricated by UNIONMELT *welding, generate the wind for high-speed tests simulating high-altitude conditions.*

The words "Heliarc," "Linde," "Oxweld," "Prest-O-Lite," "Prest-O-Weld," "Purox," "Union," and "Unionmelt" are trade-marks of Union Carbide and Carbon Corporation or its Units.

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Unit of Union Carbide and Carbon Corporation

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NEWS SUPPLEMENT AUGUST, 1947

Equipment
Personnel
Literature

Iron AND Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

SEA WATER TESTING STATION STUDIES CORROSION RESISTANCE OF METALS

▲ The sea water corrosion testing station at Kure Beach was established by International Nickel Company in 1935 for the immediate purpose of comparing the corrosion resistance of low alloy steels with carbon steel. Soon other materials were added to the program so that eventually comparative tests were being made on all kinds of ferrous and non-ferrous metals and alloys. The testing facilities have since been further extended to observe the behavior of several kinds of protective coatings — both metallic and organic, including anti-fouling formulations, the effects of marine growth on wood as well as on metals, and even the results of exposure to sea spray and sea air upon rope.

In 1940 facilities for exposing specimens to atmospheric attack were added. In connection with the latter, Carnegie-Illinois Steel Corporation, Dow Chemical Company, magnesium division, and the American Rolling Mill Company joined Inco in setting up atmospheric test racks.

At the present time, the number of specimens exposed in the atmospheric tests is about 15,000. This is believed to be the largest number of specimens on test at a single station anywhere in the world.

The number of specimens now exposed in sea water is about 2000 and during the past 12 years, the number of specimens so tested has been over 10,000.

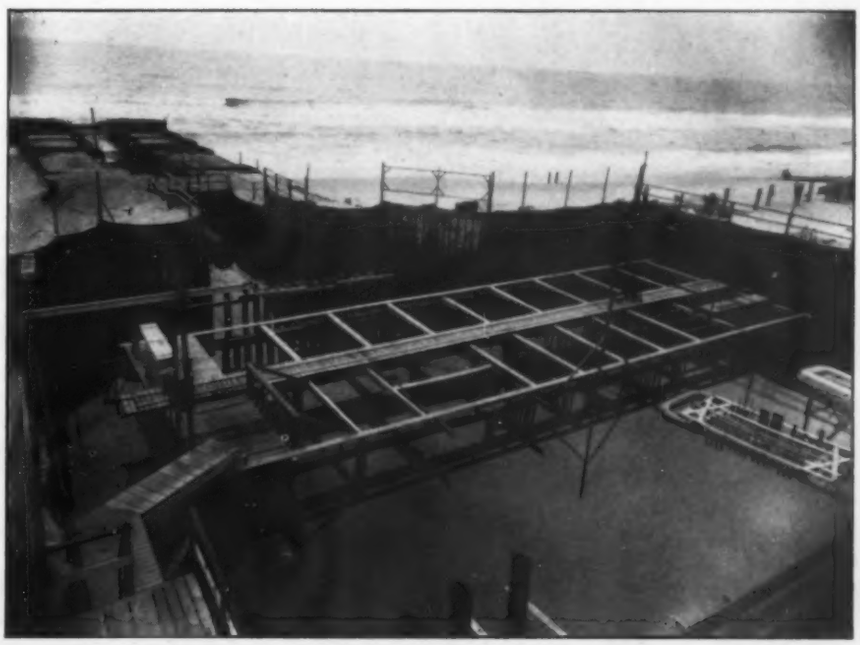
The necessity of providing facilities for the exposure of specimens to attack by sea water and marine atmospheres under natural conditions has been demonstrated by the limited practical usefulness of laboratory tests on relatively small specimens in simple salt solutions, synthetic or re-constituted sea water, or in salt spray boxes. Laboratory tests provide a valuable supplement to tests under natural conditions — particularly in preliminary investigations and in throwing light on the mechanisms of sea water corrosion and the factors that control it. However, sea water is something more than a mixture of chemicals; it is a living thing and its corrosive reactions over an extended period can be studied properly only by the exposure of specimens to attack under natural conditions.

Comparative tests at Kure Beach and in synthetic sea water in the laboratory have shown definitely that the laboratory conditions are quite inadequate for measuring the behavior of metals and alloys.

Specimens are fastened to the racks by means of Monel machine screws. Galvanic effects are prevented by the use of bakelite insulating tubes over the bolt shanks and insulating washers between the specimens and the racks and the Monel washers under the bolt heads. Incidentally, some of the original lot of Monel screws and nuts are still in use and in excellent condition after twelve years. The efficacy of this method of avoiding galvanic action has been demonstrated by the absence of such effects on specimens of such materials as magnesium, aluminum and zinc coated steel.

The period of exposure of a group of specimens may vary from six months (rarely less) to several years

This basin contains the samples which are being studied to determine the effect of spray and sea air on various metals and alloys.



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INDUSTRIAL HEATING PROBLEMS

From Soaking Pits to Forge Furnaces

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— the longest to date — twelve years. the longest to date — twelve years. The number of specimens exposed varies from about 1000 to 2000, depending on the nature of investigations in progress.

Since corrosion by marine atmospheres is equal in importance to corrosion by salt water, facilities have been provided for extensive atmospheric corrosion tests. Effects of atmospheric corrosion are measured by visual observation and by determinations of weight loss, changes in mechanical properties, or both. The test frames, with their insulators, may be made to accommodate several types and sizes of specimen. Usually a sufficient number of specimens are exposed originally to permit their withdrawal in groups of from 2 to 5 (most frequently 4) after various time intervals so as to permit observations of changes in corrosion rates with time.

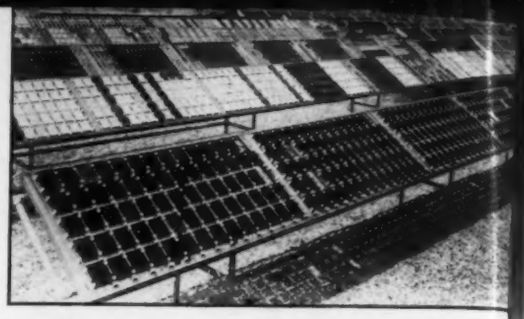
New specimens of certain key materials are put on the racks each time a large group is removed, or a new group is installed. These key specimens provide information on changes in the corrosivity of the atmosphere itself from year to year which assists in the interpretation of the results of tests made over different time periods.

One large group of about 1500 specimens of different steels was distributed over the racks at random so as to discover any possible effects of rack position on the results obtained. So far, no such effect of position has been observed.

Another important study combining sea water spray as well as sea air is being carried out on a site about fifty feet from the shore, where a stand about 8 feet high and roughly 100 feet long by 15 feet wide has been erected. This stand supports both Monel and wooden racks, some vertical and others at the same 30 degree angle used for the atmospheric tests.

The same conditions obtain here as in the atmospheric lots, except that the air frequently is laden with concentrated spray from the ocean driven by winds of varying velocity against the specimens.

One of the most important facilities at Kure Beach is the laboratory located at the site. This provides equipment for such studies as measuring loss in weight of samples, microscopic examinations, and the like. This laboratory at the site of exposure checks each specimen, keeps an accurate record of time exposure, location on racks, and carefully chronicles information on performance.



General view of atmospheric test specimens, Wilmington (Kure Beach), North Carolina.

The laboratory also includes a marine museum where sample specimens from the many studies are displayed.

There are a variety of other types of equipment and apparatus installed at the Kure Beach project to aid in the studies. These include a wooden trough in three sections at three different levels, all connected, through which sea water from the basin is pumped constantly at a velocity of 3 feet per second. The combined length of the three sections is over 300 feet and the trough has a capacity for 1000 specimens, depending upon size.

While there are many features of tremendous importance to industry included in the Kure Beach project's vast testing facilities, the most significant feature is the manner in which producers of competitive products unite to fight a common enemy — corrosion.

Data accumulated over the years are freely exchanged and available to all industry as well as to government agencies.

STEEL INDUSTRY EMPLOYEE SEPARATION RATE IS LOW

▲ The average number of workers leaving their employment in the iron and steel industry's blast furnaces, steelworks and rolling mills is well below the average separation rate for all manufacturing industries, as has been true since 1931 at least, according to a study by the American Iron and Steel Institute of U. S. Department of Labor data. These "separation" rate figures reflect voluntary and involuntary separations of workers from steel industry payrolls, as a result of quits, discharges, departures to join the armed forces, and layoffs.

In 1931, the separation rate of workers in the iron and steel group of

industries averaged 31.81 per 100 employees for the full year, as compared with 48.38 per 100 employees in all manufacturing industries.

In 1939, the rate of separation of iron and steel labor had fallen to 14.94 per 100 employees, as against 37.71 per 100 employees in all manufacturing industries. In that year, steel industry's separation rate was lower than that of any other of the 34 industrial groups upon which such data were compiled.

The effects of the war lifted industrial turnover rates as the draft called many workers into service, while others voluntarily enlisted. Despite the fact that many steelworkers entered the armed forces, the industry's low "quit rate" succeeded in holding down its average separation rate from 1943 to 1945. As a result, separations from steel jobs during those years were 30 per cent to 50 per cent lower than the average for all industries.

During 1946, general industrial unrest resulted in higher separations in most industries than were experienced prewar, although they were lower than during the war years. The largest factor in last year's separations were voluntary quits, which averaged 4.3 workers per 100 monthly for all manufacturing industries. In the steel industry, monthly quit rate during 1946 at 3.6 workers per 100 was 16 per cent lower than average in all industries.

This record not only reflects the steadiness of employment in steel in recent years, but also indicates the high pay and good working conditions.

GE ENGINEERS STUDY NATION'S ORE PROBLEM

▲ Plans by Lake Superior district iron mining companies for large-scale refining of low-grade iron ore to guarantee American industry a continued supply of high-grade iron are attracting the interest of the engineers of the General Electric Company.

Iron ore companies are turning to the refining or "beneficiation" process, as it is popularly known in the industry, on an industry-wide basis because the supply of high-grade ores will be exhausted in from 20 to 30 years at the present rate of consumption. engineers said.

With beneficiation, the low-grade ores, now plentiful but unmarketable

more power WITH READY-POWER

Ready - Power - equipped Elwell Parker Up Ender handling heavy steel coils.

FOR ELECTRIC TRUCK OPERATION AT ITS BEST!

Ready-Power-equipped electric trucks provide more power for heavy loads, more continuous hours of service and more materials handled in any given period. Dependable electric power is generated right on the truck chassis by an engine-driven, direct-current generator. Get the most out of your electric trucks. Convert them to Ready-Power. Specify Ready-Power on your new trucks. Write for descriptive literature.

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because of their low iron content, will be refined near the mines to increase the grade prior to shipment. Only by this method can the Lake Superior district, which includes the rich Minnesota Mesabi range, continue to supply about 85 per cent of the nation's annual 60 million to 70 million-ton-supply of iron ore, engineers explained.

Electric equipment will be needed by the mining companies in crushing and screening, concentration, and sintering plants, where most of the equipment will be electrically powered, engineers said. This equipment will include generators, motors, transformers, unit substations, switchgear, controls, and other electric apparatus.

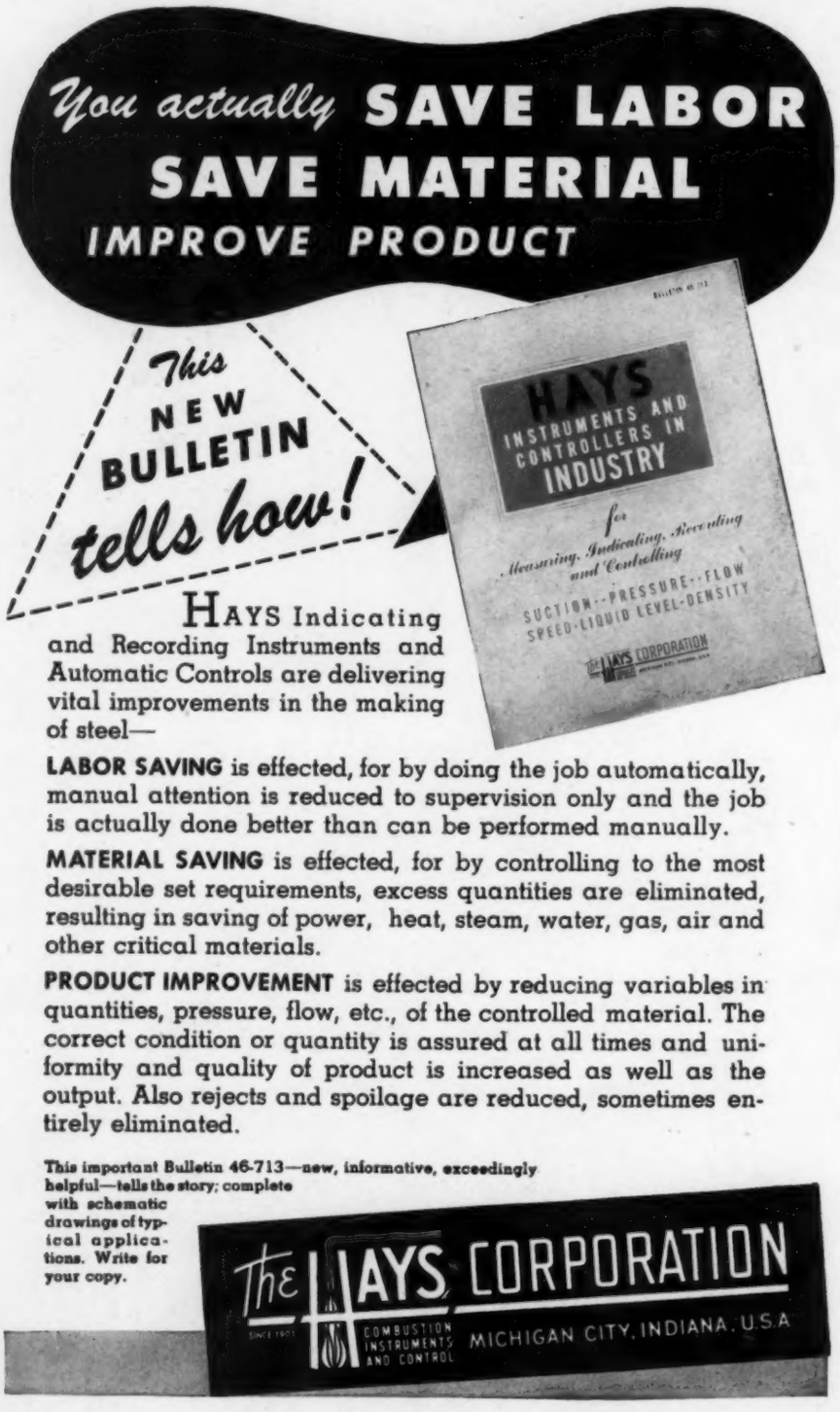
General Electric is now supplying some of this equipment for pilot plants in the early stages of the beneficiation program. The company has assigned a special staff of engineers to study approved and new electric systems for the process, and experience is being gained from these industries which have used beneficiation methods for many years.

The new development will also have an important bearing on the power companies in the mining district. Engineers said the new process would require from 60 to 80 kilowatt hours per ton as compared to 1½ to 4 kw hr per ton average for the present methods, which, in most cases, consists only of crushing and washing some ores before shipment.

Two major wars and the great demand for steel products already in the 20th century have resulted in a drain on the high-grade deposits, which were naturally beneficiated by the forces of Mother Nature. Aware they are facing a time limit on high-grade ore production, the mining companies are taking over nature's job on the low-grade ores, and directing their research and economic efforts to beneficiation, it was explained.

The low-grade ores contain about 30 per cent iron. Known in the iron ore industry as "taconite," it must be refined for smelting, engineers pointed out. Of all Lake Superior ore produced today, only 20 per cent is now beneficiated and shipped to supplement the balance of high-grade ores.

When suitable processes have been worked out this percentage will become higher, and engineers predict that nearly 100 per cent of all the ore produced three decades from now will be the low-grade variety, and will require beneficiation.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HAYS Indicating and Recording Instruments and Automatic Controls are delivering vital improvements in the making of steel—
LABOR SAVING is effected, for by doing the job automatically, manual attention is reduced to supervision only and the job is actually done better than can be performed manually.
MATERIAL SAVING is effected, for by controlling to the most desirable set requirements, excess quantities are eliminated, resulting in saving of power, heat, steam, water, gas, air and other critical materials.
PRODUCT IMPROVEMENT is effected by reducing variables in quantities, pressure, flow, etc., of the controlled material. The correct condition or quantity is assured at all times and uniformity and quality of product is increased as well as the output. Also rejects and spoilage are reduced, sometimes entirely eliminated.
This important Bulletin 46-713—new, informative, exceedingly helpful—tells the story; complete with schematic drawings of typical applications. Write for your copy.
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MICHIGAN CITY, INDIANA, U.S.A.

MAGNET CRANE SPEEDS MATERIALS HANDLING

▲ Operators looking for ways to cut the cost of scrap unloading and loading should find the overhead crane installation in the yard of Joseph Smith and Sons interesting. This large Washington, D. C., yard recently began operating a Harnischfeger P&H 10 ton heavy duty magnet crane. With a 110 foot span and mounted on a 300 foot runway 30 feet from the ground, it is possible to reach any part of the yard at any time. Overhead handling gives them immediate access to every scrap pile, freight car, baler, shears, or truck. There is no lost time in moving around scrap piles or clearing roadways. Rain and mud, which restrict equipment that moves on the ground, do not hamper

(*Please turn to page 118*)

ALWAYS LOOKING INTO THE FUTURE

Injecting oxygen into the molten steel bath

another Airco first

Today, steel making in the Open Hearth stands on the threshold of far reaching developments thanks to the cooperation of leading steel mills with Airco research.

The basis of this research is Airco's development of a practical method of injecting oxygen directly into the molten steel bath through the slag cover.

This opens up new avenues of approach in controlling, and in materially reducing the refining period.

Yes, tomorrow's steel will be produced faster due to this important use for oxygen . . . as developed by Airco technicians.

This promising new technique, which is exciting the imagination of steel makers, is another outstanding example of Airco's continuing effort to provide time-saving, product-improving tools and processes for ALL industry. The facilities of our Technical Sales Division are available to you in applying Airco techniques and products to the solution of your problem.

If you desire further information about this process, please direct your request for a copy of our bulletin, "Use of Oxygen In The Open-Hearth Bath", to Dept. 5650, Air Reduction, 60 East 42nd St., New York 17, N. Y. In Texas: Magnolia Airco Gas Products Company, Houston 1, Texas.

AIRCO **AIR REDUCTION**

Offices in All Principal Cities

Originators of Modern Oxyacetylene Flame and Electric Arc Methods For ALL Industry

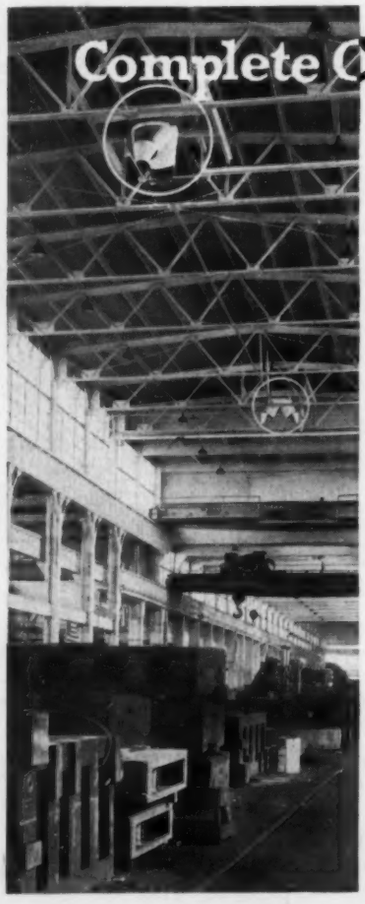
operation of the crane. Work goes on under all conditions. Also, this method eliminates rehandling as the crane can load or unload direct from one place to any other in the yard. It simplifies separation by permitting classified scrap to be moved directly to cars or desired storage areas.

These benefits, ability to work anywhere in the yard and through any weather, have made it possible to greatly speed the handling and loading of scrap in this yard, and at the same time cut costs. Another feature of overhead handling that adds still further to this savings is its immediate operation. With electric power, the crane is ready for service the minute the operator takes his place at the controls.

TRUCK DOES CRANE WORK WITH DETACHABLE BOOM

Making a single fork truck quickly adaptable both for work usually requiring motorized slewing cranes and for that requiring standard fork truck equipment, this is a new interchangeable motorized slewing boom attachment for fork trucks just announced by Automatic Transportation Company.

The boom is designed for maximum versatility. It is manually adjustable in outreach from 54¼ to 108¼ in.; it is vertically adjustable from horizontal to an upward angle of 30 degrees; and it swings horizontally 60 degrees to either side of center. Mounted on a standard 6000-lb capacity Automatic fork truck chassis, as shown above, the boom will handle 1100-lb loads at the maximum outreach and 1820 lb when in closed position. Maximum height of the hook is 18 ft 5 in.



WING Revolving Unit Heaters deliver the heated air in slowly moving streams covering successively every point in a complete circle. From their overhead locations, they project the heated air in a constantly changing direction of flow, causing it to mix uniformly, move around and under obstructions, reaching walls and remote corners and avoiding concentrated blasts of heated air. In summer with the steam turned off, it creates a delightful cooling effect. Write for bulletin.

L. J. Wing Mfg. Co.

142 W. 14th Streetf New York 11, N. Y.
Factories: Newark, N. J. and Montreal, Can.

Wing
REVOLVING
UNIT HEATERS

NEW FURNACES UTILIZE PREPARED ATMOSPHERES

▲ The balanced carbon oxide atmosphere furnace and gas carburizing furnace are two new prepared atmosphere furnaces that Surface Combustion Corporation has added to its standard-rated line of heat treating furnaces.

A distinctive characteristic of RX gas, utilized as the protective atmosphere, in addition to being non-oxidizing is that its carbon potential can be accurately controlled to be in perfect balance with a desired carbon content of steel. This makes it possible to obtain a scale free, heat treated product with a selected surface carbon content. Formerly available only for specially designed furnaces, the balanced carbon principle of heat treating is now available to users of smaller standard furnaces.

The RX atmosphere used in these furnaces is produced by a patented process which consists of passing a rich air gas mixture of either natural or a petroleum gas through a heated tube filled with a catalytic refractory material. The resultant atmosphere is composed for approximately 20 per cent carbon monoxide, 40 per cent hydrogen and 40 per cent inert nitrogen. For high carbon balances RX gas is enriched to the required degree with additional undiluted natural or petroleum gas.

The atmosphere furnaces are of the horizontal muffle type, externally fired, with the generator built as an integral, but separately heated, part of the unit. They are of two general types: superheat (2000 to 2400 F) and general heat treat (1400 to 1850 F). For operation at lower temperature the latter series can be modified by the addition of pilots for off-on operation.

Any air infiltration that might occur around the door openings is opposed by the flow of the gas through the furnace. A large volume of atmosphere gas is introduced from the generator into the rear of the muffle, flows forward and discharges through an outlet at the front of the muffle. The vented muffle gas is burned at a vent above the furnace and is kept continuously ignited by a small gas burner.

The carburizing furnaces may be

(*Please turn to page 124*)

Double Headstock Roll Lathe by CONTINENTAL

Continental
ROLL LATHES

Master Tools by Experienced Craftsmen

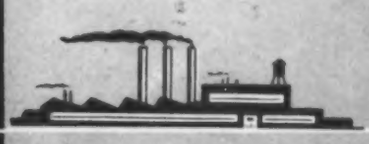
MASTER TOOLS most frequently originate with the creators of the initial product. **CONTINENTAL** combines a close working knowledge of roll manufacture and roll turning with extensive machinery and rolling mill experience to produce the ultimate in modern, Chatter-proof Roll Turning Lathes.

Continental

Continental
FOUNDRY & MACHINE CO.

CHICAGO · PITTSBURGH

Plants at EAST CHICAGO, IND. · WHEELING, W. VA. · PITTSBURGH, PA.



INDUSTRY'S HEADQUARTERS FOR
CARBON AND ALLOY STEEL CASTINGS
ROLLING MILLS AND EQUIPMENT
IRON AND STEEL ROLLS

For all these . . .

Your LOGICAL Source is

Continental

Alloy and Carbon
STEEL CASTINGS for

Boiler, Tank and Piping · Bridge Construction

Chemical and Paint Works · Dredges

Electrical and Hydro-Electric Equipment

Foundry Equipment · Gears, Pinions and Worms

Hammers, Presses, Crushers, Cement Mills and Heavy Metalworking Machinery

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Power Shovels, Locomotive Cranes, Hoists, Derricks, and Heavy Construction Equipment

Railroad Locomotive and Car Builders

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Rolling Mill, Blast Furnace and Steel Plant Equipment

Ship, Marine and Dock

Steam Turbines · Sugar Mills

Sizes from
50 to 250,000 pounds!

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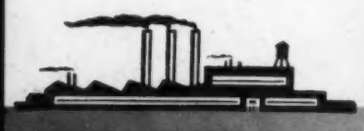
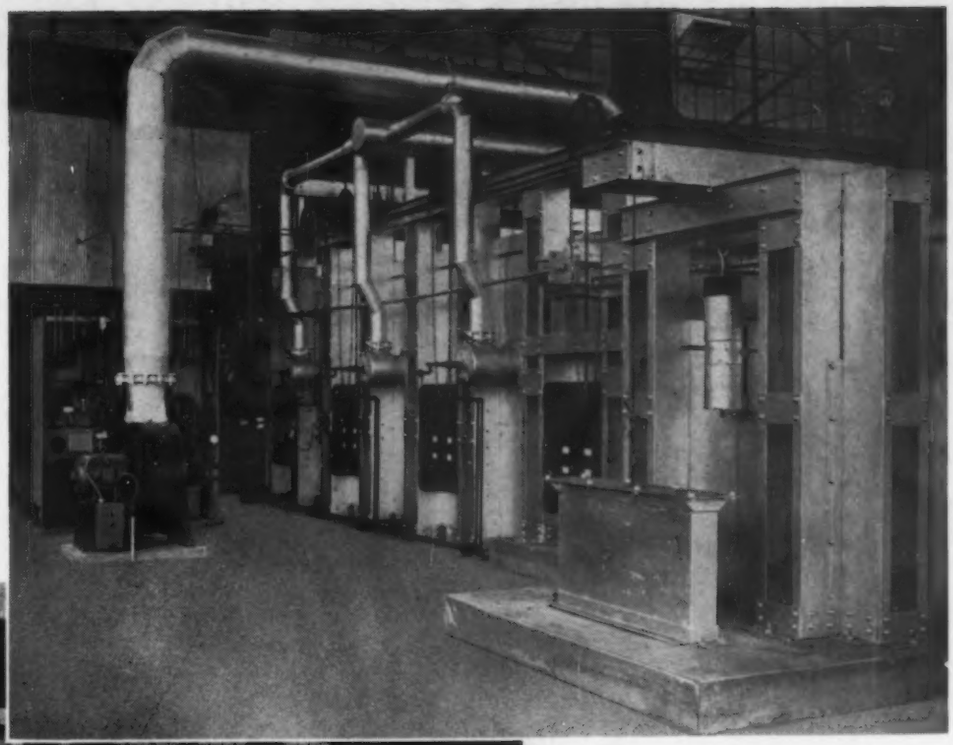
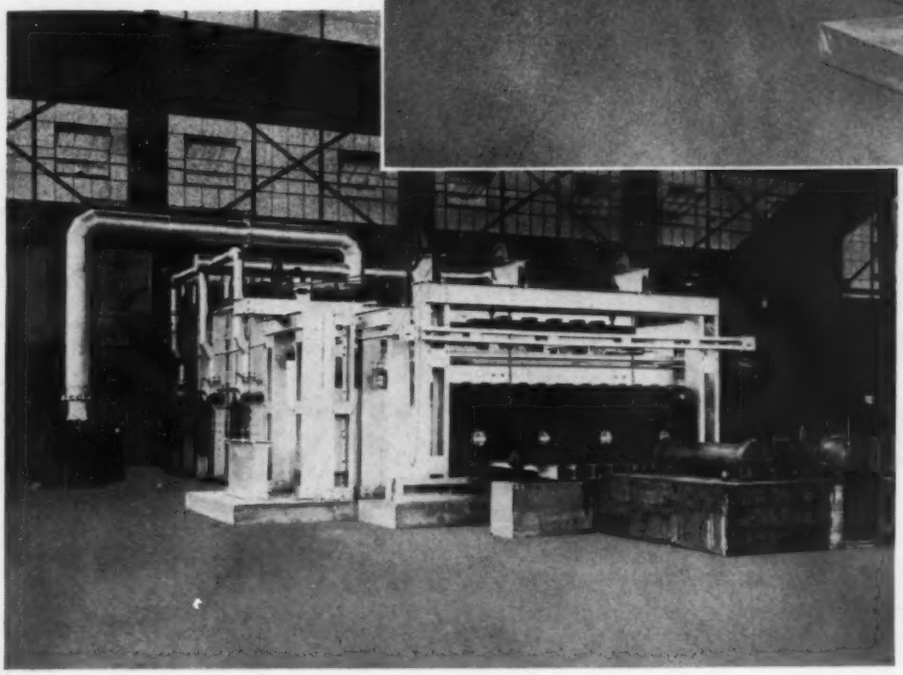
FOUNDRY & MACHINE CO.
CHICAGO · PITTSBURGH
Plants at EAST CHICAGO, IND. · WHEELING, W. VA. · PITTSBURGH, PA.



INDUSTRY'S HEADQUARTERS FOR
CARBON AND ALLOY STEEL CASTINGS
ROLLING MILLS AND EQUIPMENT
IRON AND STEEL ROLLS

Capacity 8 to 10 tons per day depending upon slab or ingot sizes — and on the steel analysis





All-fired with provision for future application of gas firing.

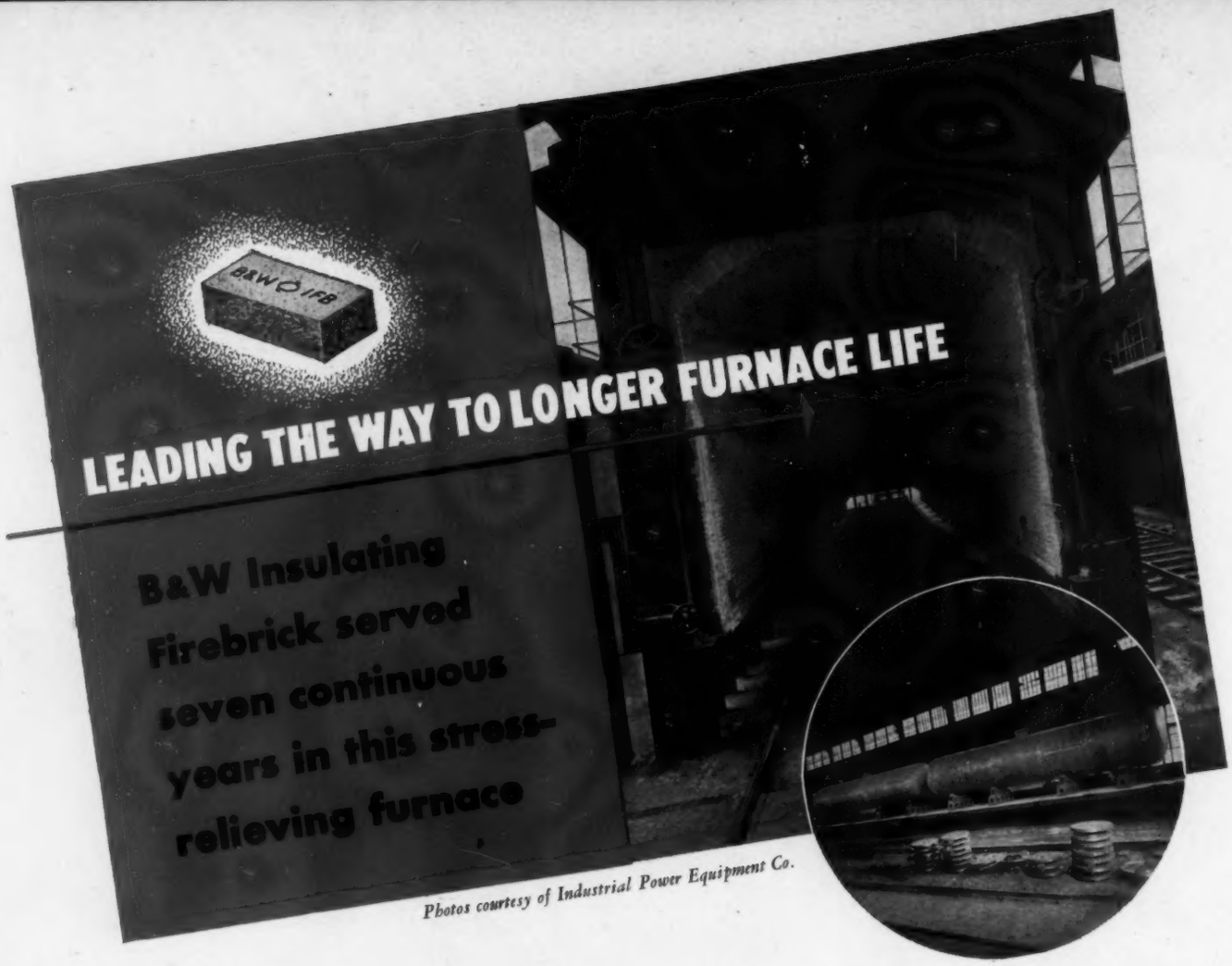
CONTINUOUS PUSHER TYPE FURNACE

This modern Pusher Type Furnace has completely automatic Temperature Combustion and furnace pressure control and allows for selective discharge by use of a manipulator. The Pusher is constructed so that one to five rows of material can be pushed through furnace in any desired pattern.

Write for full particulars.

610 SMITHFIELD ST. **LOFTUS ENGINEERING** *corporation* PITTSBURGH, PA.

Designers and Builders — Engineers, Consultants, Contractors


B&W IFB
LEADING THE WAY TO LONGER FURNACE LIFE
B&W Insulating Firebrick served seven continuous years in this stress-relieving furnace

Photos courtesy of Industrial Power Equipment Co.

Details of Rebuilt Furnace

Length — 95 feet 4½ inches
Width — 13 feet
Height — 17 feet 7½ inches

Sidewalls and end — 9" B&W K-23 I.F.B. Backed with 4½" B&W K-20 I.F.B. Door and arches—9" B&W K-23 I.F.B. Car top —4½" heavy firebrick, 2½ inches B&W K-20 I.F.B., 2" B&W K-20 Concrete Mix. All B&W I.F.B. laid up in B&W Smooth-set Mortar.

In 1939 this large stress-relieving furnace was built by the Industrial Power Equipment Company for the Milton, Pa. plant of the American Car and Foundry Company. Side walls, end wall, arch and door were constructed of B&W Insulating Firebrick. The car was protected by layers of B&W Insulating Concrete and B&W Insulating Firebrick, topped off with a layer of firebrick.

For seven years, these refractories stood up under continuous, severe service.

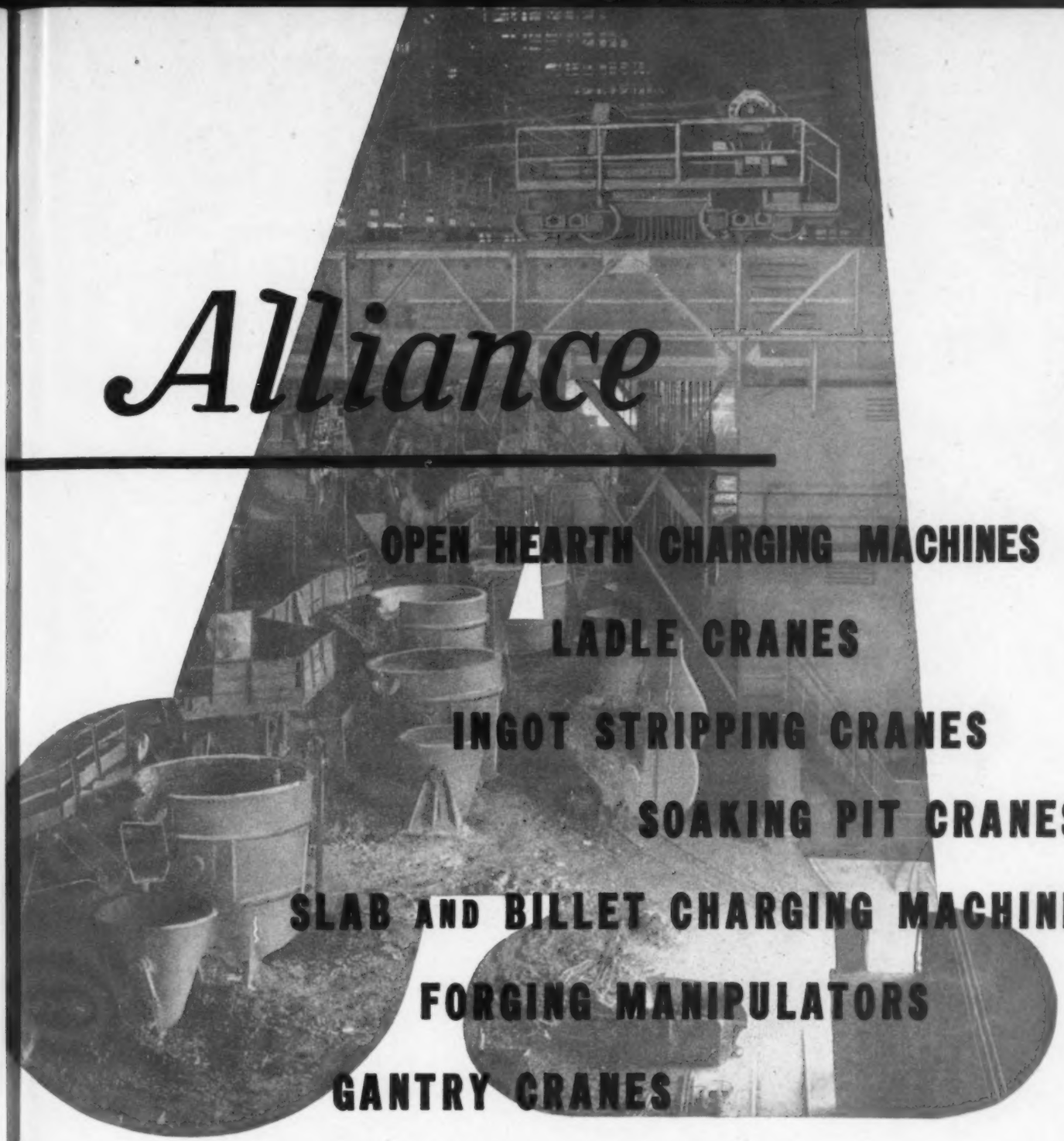
In 1946, when this furnace was enlarged and rebuilt, complete satisfaction led to re-specifying B&W Refractories throughout! B&W Refractories are leading the way to more efficient furnace operation in all types of industries. Your local B&W Refractories Engineer will gladly show you how they can benefit you.

R-290

Water-Tube Boilers, for Stationary Power Plants, for Marine Service . . . Water-Cooled Furnaces . . . Superheaters . . . Economizers . . . Air Heaters . . . Pulverized-Coal Equipment . . . Chain-Grate Stokers . . . Oil, Gas and Multifuel Burners . . . Seamless and Welded Tubes and Pipe . . . Refractories . . . Process Equipment.

BABCOCK & WILCOX

THE BABCOCK & WILCOX CO.
REFRACTORIES DIVISION
GENERAL OFFICES: 85 LIBERTY ST., NEW YORK 6, N.Y.
WORKS: AUGUSTA, GA.



Alliance

OPEN HEARTH CHARGING MACHINES

LADLE CRANES

INGOT STRIPPING CRANES

SOAKING PIT CRANES

SLAB AND BILLET CHARGING MACHINES

FORGING MANIPULATORS

GANTRY CRANES

ORE AND COAL BRIDGES

SPECIAL MILL MACHINERY

STRUCTURAL FABRICATION

The Alliance Machine Company

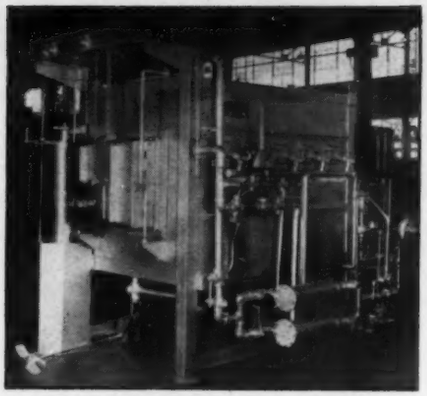
MAIN OFFICE:
ALLIANCE, OHIO

PITTSBURGH OFFICE:
1622 OLIVER BUILDING, PITTSBURGH, PA.

(*Continued from page 118*)

also be used for heat treating all types of steel in a balanced carbon atmosphere, as well as for gas carburizing. The carburizing medium is gas atmosphere enriched with natural or petroleum gas to obtain a high carbon potential for a rapid rate of carburization. The units are of the horizontal muffle type, externally fired with the atmosphere generator included as an integral, but separately heated, part in the rear of the furnace casing. An atmosphere recirculating system with an electric driven pump draws the atmosphere from the front end of the muffle, through a filter, and reintroduces it into the rear of the muffle under pressure. The inlet gas stream is projected into a venturi throat in the top of the muffle to inspirate a large volume of the atmosphere from within the muffle and create a rapid circulation of gases around the parts being carburized.

An inlet for admitting the enriching gas into the circulating system is provided in the inlet connection to the pump. Excess gas is vented and ignited at the outlet in the same manner as described previously for the atmosphere furnace. The furnace operates at a temperature from 1400 to 1850 F and can be heated from cold in about 2½ hours. The rate of carburizing for SAE 1020 steel at 1700 F ranges from 0.94 hours for a case depth of 0.020 to 12.00 hours for a case depth of 0.070 (measured to core analysis).



The atmosphere used in these furnaces is produced by a patented process.

PEERLESS PUMPS
add a "plus"
TO DEEP WELL PUMP PERFORMANCE

Peerless Pumps offer the widest range of water capacities from 15 to 30,000 gallons per minute from all depths

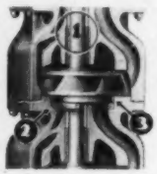
*

Peerless Pioneered in the development of water from wells of great depth.

Available in water or oil lubricated types. Pre-tested to meet exact conditions of well and application.

Top-Flight Quality Underground From Patented Double Bearing—Double Seal Bowl Construction

Double Bearings (1) one bronze and one Goodrich Cutless Fluted Rubber bearing for each pump bowl add double life to bearings and impeller shaft. Double Seal (2) mounted below impeller neck (3), is a durable, resilient ring — automatically compensating for wear.



Choice of Pump Drives

Contributing to the over-all operating adaptability of Peerless Deep Well Turbine Pumps are the optional type Peerless drives. Moturbo (electric) heads are available from 1 to 1,000 h.p. Gearturbo (geared) heads range from 1 to 300 h.p. All types are highly advanced in design and are proved through years of operation under every pumping condition. Also furnished are Veeturbo, (V-belt) and Belturbo, (flat belt) and combinations of these drives.

Peerless Turbine design permits wide adaptability to diversified applications

Peerless turbine pumps are the choice of industry and municipalities for an ever dependable source of clean, constant temperature water. Also available: Close-coupled type Peerless Turbine pumps for pumping from shallow pits, sumps, or surface water sources. With proper fittings Peerless Turbine pumps are Underwriters' approved for adequate independent plant fire protection.

Request Bulletins.

PEERLESS PUMP DIVISION
Food Machinery Corporation

Factories: Indianapolis, Indiana • Quincy, Ill. • Los Angeles 31, Calif.
District Offices: Canton 2, Ohio; Philadelphia: Suburban Square, Ardmore, Pa.
Atlanta: Rutland Bldg., Decatur, Ga.; Dallas 1, Texas; Los Angeles 31, Calif.

OIL AND GAS INDUSTRY MAJOR TUBE CONSUMER

▲ During 1946, the oil and natural gas industry maintained its position as a major user of steel pipe and tubes, accounting for 26 per cent of total shipments of these products, according to preliminary data prepared by the American Iron and Steel Institute. Total 1946 shipments to the industry at 1,225,425 net tons of tubular products, almost equalled the total of 1,228,642 net tons shipped to the group in 1940. Of that total amount shipped to the oil and gas industry during 1946, 716,424 tons went to jobbers, dealers and distributors of such products, which was the largest amount received by this group since 1940, with the exception of the abnormal war-peace year of 1941. Another 419,995 tons went directly to the oil and natural gas industry for construction purposes, including the building of pipelines, and 89,006 tons went to the industry for other purposes.

The steel industry produced 4,633,231 tons of steel pipe and tubing in 1946, and about eight per cent or 385,000 tons were exported.

EMPIRE STEEL COMPLETES LARGE BOILER PLANT

▲ Empire Steel Corporation, Mansfield, Ohio, announced the near completion of a new $250,000 boiler plant and also provisions for an expenditure of $60,000 for burner and oil storage tank facilities as stand-by equipment in case of further natural gas curtailment during the winter months. There has been a total of $830,000 provided for new capital improvements in the last 18 months. Aside from these expenditures for capital improvements, a total of $475,000 has been spent during 1947 on proper maintenance of the company's equipment and expenditures of this character will be continued. These actions place the company in a better position to continue its maximum operation and to project the continued success of the company in future years.

The volume of sales and earnings in 1947 continues at a higher rate than in 1946, allowing for the work stoppage during that year. It has been and will continue to be the policy of the board of directors to equitably apportion the available tonnage of the various products regularly manufactured by the company among its old and well established customers, so as to maintain a backlog of most desirable accounts for a period of more normal operations in the future.

The company paid to its employees a total of $250,000 last week, which included the benefits provided by the recent labor contract with the Union, including vacation pay allowances as well as increases to the salaried payroll.

CUTTING TORCH AVAILABLE WITH PRE-WAR QUALITY

▲ The Air Reduction Sales Company's "Series 9000" cutting torch with monel metal head and stainless steel tubes, discontinued during the war years because of a shortage of critical materials, is once again back on the market. This "quality" torch offers features not to be found in any other cutting torch. For example, the torch head, made of durable monel metal assures long trouble-free service; the tubes, made of stainless steel offer great rigidity and heat resistance; the stainless steel lever and

(*Please turn to page 128*)

"Sure, MATHEWS Builds *Heavy* Equipment"

A very high percentage of Mathews engineering time is devoted to the design of heavy equipment. The development of heavy-duty Roller Conveyers, heavy chain conveyers, and special conveying machinery for handling very heavy loads is a great part of Mathews complete conveying service to industry. Because Mathews package handling systems are so prominent, the question sometimes arises as to whether or not Mathews Engineers are at work in the heavy conveying equipment field. When this occurs, there is usually an experienced plant engineer who has seen Mathews Conveyers at work under severe conditions in foundries, brass mills or steel plants, and who will remark, "Sure, Mathews builds heavy equipment." — And he's right — for whether the weight of a load is rated in pounds or tons, if it must be handled, it is a job for Mathews Engineers.

MATHEWS CONVEYER COMPANY
ELLWOOD CITY, PENNSYLVANIA

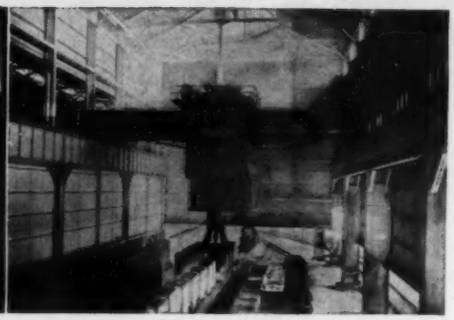
MATHEWS CONVEYER COMPANY WEST COAST
SAN CARLOS, CALIFORNIA

MATHEWS CONVEYER COMPANY, LTD.
PORT HOPE, ONTARIO

Engineering Offices or Sales Agencies in Principal American and Canadian Cities

Gears used at Republic Steel plants.

Brosius charging machine.



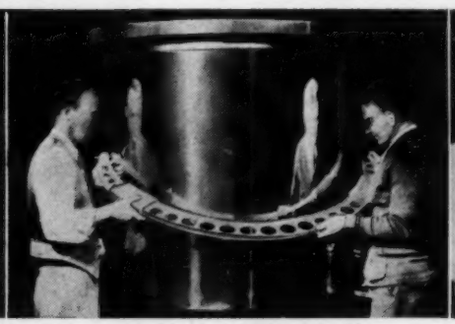
Morgan ingot stripper.

Why are highly stressed parts of steel mill machinery made of NICKEL ALLOY STEELS?

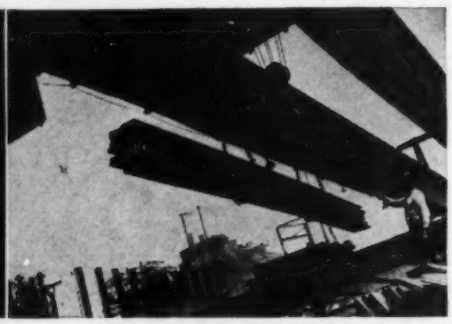
...because NICKEL Alloy Steels provide:

- High strength-weight ratios in heavy sections that permit reducing weight and inertia of moving parts. Lighter parts require less power for starting, stopping and reversing.
- Stamina to resist repeated impacts and reversals of stress at both normal and sub-zero temperatures thus reducing breakage.
- Wear-resistant surfaces that last longer.
- Mill engineers who know steel from experience achieve economy by specifying Nickel alloy steels for heavy duty service. A helpful booklet, "Alloy Steels for Plant Maintenance Applications," is yours for the asking... write for a copy today.

Mesta rolling mill pinions.



Morgoil bearing journal sleeve.

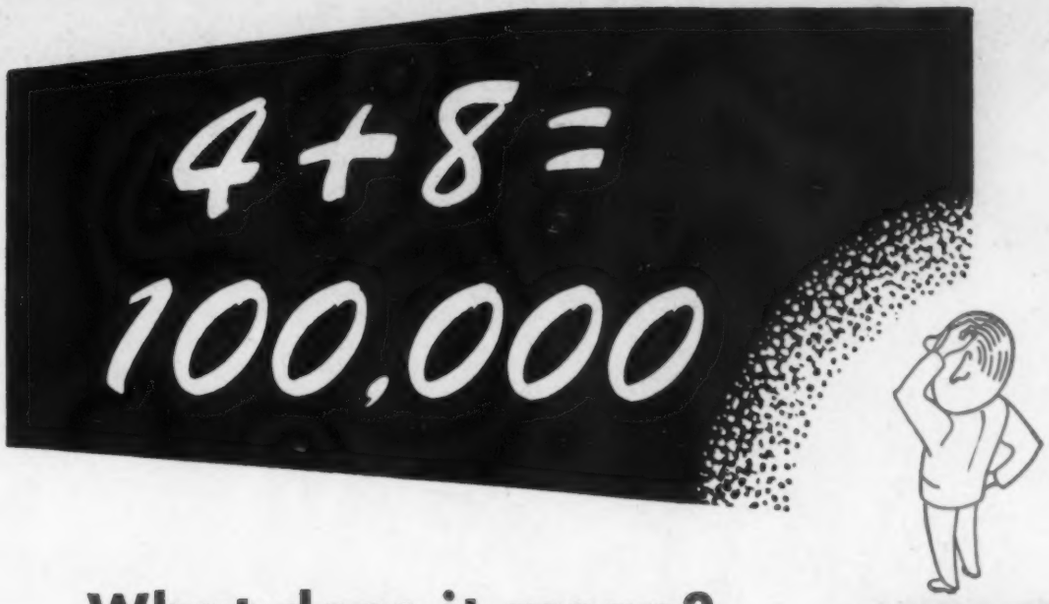


Accalloy sling chains.

EMBLEM OF INCO SERVICE
TRADE MARK

Over the years, International Nickel has accumulated a fund of useful information on the selection, fabrication, treatment and performance of engineering alloy steels, stainless steels, cast irons, brasses, bronzes and other alloys containing Nickel. This information is yours for the asking. Write for "List A" of available publications.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.



What does it mean?

Just this—with 4 basic circuits and 8 basic component parts you can get over 100,000 different combinations of Bailey electronic instruments and controls for flow, temperature, level, speed, gas analysis, etc. Furthermore, parts are interchangeable.

Look how this simplifies your instrument problem. By specifying Bailey, you automatically reduce your stock of replacement parts. You begin to standardize your instruments as you do other equipment in your plant. And that means reduced maintenance costs.

Maintenance men need less training—they quickly become familiar with the standardized Bailey parts—no time is lost in exploring a multiplicity of specialized equipment. For example—the amplifiers, slidewire units, and other basic components are standard for all combinations of Bailey electronic instruments.

Write today for bulletin 17. You should have a copy in your file for ready reference the next time you specify process controls. Meanwhile, remember—4 plus 8 will give you over 100,000.

Bailey Electronic Recorder

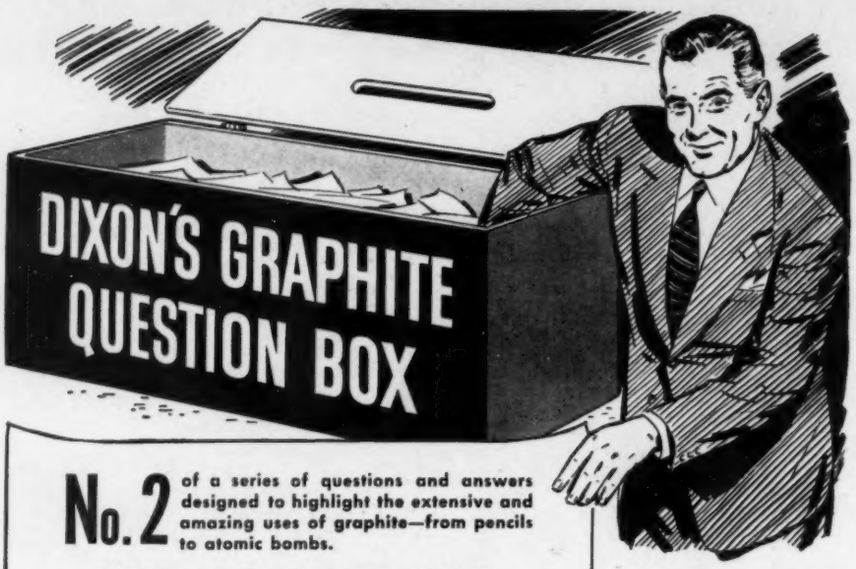
Save 3/4
OF YOUR PANEL SPACE

This is typical of the advantages you get with Bailey instruments and controls. The 4-pen Pyrotron makes the same number of continuous records as four separate recorders. Each pen is actuated by a separate system. It draws a continuous record in a distinctive color. Package units are interchangeable. Our bulletin 230-A describes this space-saving unit in detail.

P-13

BAILEY METER COMPANY
1047 IVANHOE ROAD
CLEVELAND 10, OHIO

Controls FOR THE IRON & STEEL INDUSTRY
Temperature • Pressure • Flow • % Oxygen • % Combustibles • Level • Density • Ratio



No. 2 of a series of questions and answers designed to highlight the extensive and amazing uses of graphite—from pencils to atomic bombs.

SOURCE AND PROPERTIES OF GRAPHITE

QUES. Are all graphites—varying in type, purity and particle size—suitable for the same uses?

ANS. Definitely not. In nearly every case, each application governs the selection of graphite in type, purity and particle size. Lubricants require the crystalline types of highest purity. Electrical applications usually require high purity. The lower purity grades of natural amorphous graphites find less exacting uses.

QUES. What are the characteristics of graphite that make it one of mankind's most useful industrial minerals?

ANS. It is extremely lubricous or slippery, lustrous, oil-and-grease-free (unless processed with such), and withstands excessive heat, cold and pressures. It neither destroys nor is destroyed by contact with water, oil or any chemical. It is electrically conductive, heat conductive, non-magnetic, non-fusible, non-toxic, non-odorous and does not permanently stain. It adheres tenaciously to almost all substances and has a low co-efficient of expansion.

QUES. What was the first product made from graphite?

ANS. Pencils, in 1554.

QUES. Is graphite processed into all required forms and shapes that make it usable for innumerable manual, mechanical, chemical, and electrical applications?

ANS. Graphite owes its remarkable versatility to its almost unlimited scope of form and formulation. It is available in a wide variety of microscopic powders, large flakes, fluids, non-fluids, concentrates, bars, tubes, sheets, plates and specially processed shapes.

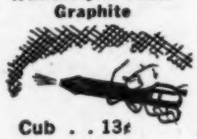
QUES. In what products or processes is graphite now principally used?

ANS. Lubricants • Pipe joint seals • Mechanical packings • Gaskets • Brake linings • Sand and metallic molds • Lustrous heat-resisting polishes • Protective coatings • Crucibles and refractories • Electronics • Electroplating • Electrodes • Dry batteries • Motor and generator brushes.

A few of thousands of widely used products containing Dixon's Graphites. Those starred are Dixon's products, many of them sold by supply houses everywhere.

★ Ticonderoga Flake Graphites Nos. 1 & 2

★ Microfyne Flake Graphite



Cub . . 13¢

Type 4 . 40¢

★ Graph-Air Guns

Now may we receive *your questions* on how graphite can help *you?*

DIXON'S GRAPHITES

Products of

JOSEPH DIXON CRUCIBLE COMPANY

Jersey City 3, N. J. D Div.

LOOK FOR No. 3

in this series. We will gladly send you reprints of any you may miss.

(*Continued from page 125*)

ribbed handle have been expertly designed to afford maximum ease of operation. Moreover, all connections are silver brazed to assure permanent leak proof service.

In addition to its sturdy construction and modern design the cutting torch is truly versatile. A total of 22 interchangeable cutting tips are available for this torch making it adaptable for every practical hand cutting operation from removing rivet heads by washing to cutting sheet metal and trimming plate.

The standard torch is 21 in. long and weighs 3 lb and 4 oz. It is usually supplied with 75 or a 90 degree head but straight heads are also available. Swivel type hose connections for ¼ in. on 5/16 in. inside diameter hose are supplied with each torch.

KAISER STEEL AGAIN ESTABLISHES RECORDS

▲ The iron and steel division of the Kaiser Company, Inc., established new records at Fontana, California, during the month of June 1947:

	June 1947	Previous record May 1947
Soaking pits	68,206	64,942
Plate (postwar)	16,802	14,655
36 in. mill products	56,855	53,235

CARNEGIE-ILLINOIS USES COLOR IN COKE PLANT

▲ Color plays an important part in promoting safety and improving working conditions in the basement of the new No. 22 battery of coke ovens at the Clairton coke works of Carnegie-Illinois Steel Corporation. Just as the cellar of a house once was considered as the last place in the home that needed fixing up, so has a coke battery been disregarded as a place where modern theory of color dynamics could be applied. One glance at the basement of the new battery will change that opinion, however, for the transformation accomplished is remarkable and represents a long step

The use of color dynamics to improve working conditions is gaining in the steel industry.

forward in coke plant design, safety and operation.

The basement lies directly underneath the ovens, which are supported on symmetrically placed concrete foundation columns and girders. Inverted bracket lamps, located about half way up on alternate columns, provide excellent indirect light throughout the area. The improved lighting alone would serve to avoid the former impression that a coke oven basement is a drab mass of dusty concrete construction, smoky from numerous small fires, and cluttered with one kind or another of equipment or even debris.

Under the new No. 22 battery the basement is painted in clean, attractive, restful colors and the floor is red colored cement. Cascade blue, one of the coolest colors known, is used on the ceiling, which is the hottest area. For the columns, a cheerful sun-tan shade has been used. Tile red bands encircle the bottom 18 inches of the columns, and the same color was used to color the floor cement before it was waxed. Piping, gas inlets, valves, etc. are painted black and cream for easy identification.

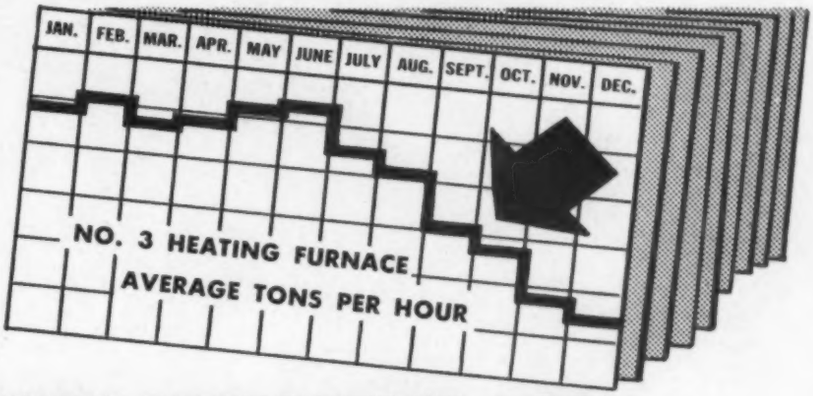
Color alone, however, will not actually reduce the heat, even though it is highly effective from a psychological point of view. Heat, therefore, is dissipated by means of forced air circulation, cool incoming air being distributed across the basement through louvers in a wind tunnel that extends along the coke side of the basement.

All air required for combustion must cross the basement from the coke to the pusher side before entering the regenerators. To assure maximum cooling of the basement, however, two to three times as much air is required for combustion is circulated, excess air escaping through openings around the pusher side buckstays. This positive pressure reduces infiltration of dust and smoke and aids in clearing the atmosphere of any fumes, smoke or dust incident to basement operations. Experience thus far indicates that it is possible to maintain basement temperatures within 10 to 15 F above atmospheric temperature.

REPLACE SWITCHBOARD AT IRVIN SLAB FURNACES

▲ An intricate electrical control board for three slab reheating furnaces at Carnegie-Illinois Steel Corporation's Irvin works will be completely replaced while normal production schedule is maintained, under a $27,000 contract just awarded Alle-

(*Please turn to page 132*)

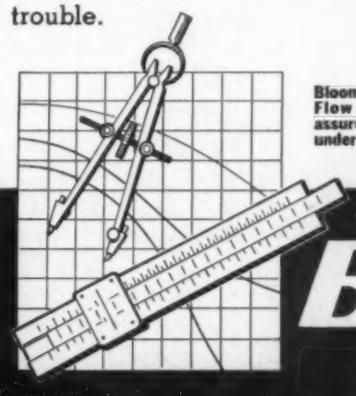


WHEN PRODUCTION LAGS···

SEE BLOOM ENGINEERING

When furnace output needs "pepping-up"—when fuel costs rise—let Bloom Engineering investigate the cause of your trouble. Extensive experience with heating furnaces of all types enables our engineers to analyze conditions and suggest a remedy. Perhaps a relocation of burners is needed; perhaps a more uniform flow of fuel—the solution may be simple or difficult. Whatever it is, you can use our knowledge of furnaces and combustion to correct the conditions that are causing your trouble.

Bloom Constant Flow Oil Valve assures uniform fuel flow under varying pressures.

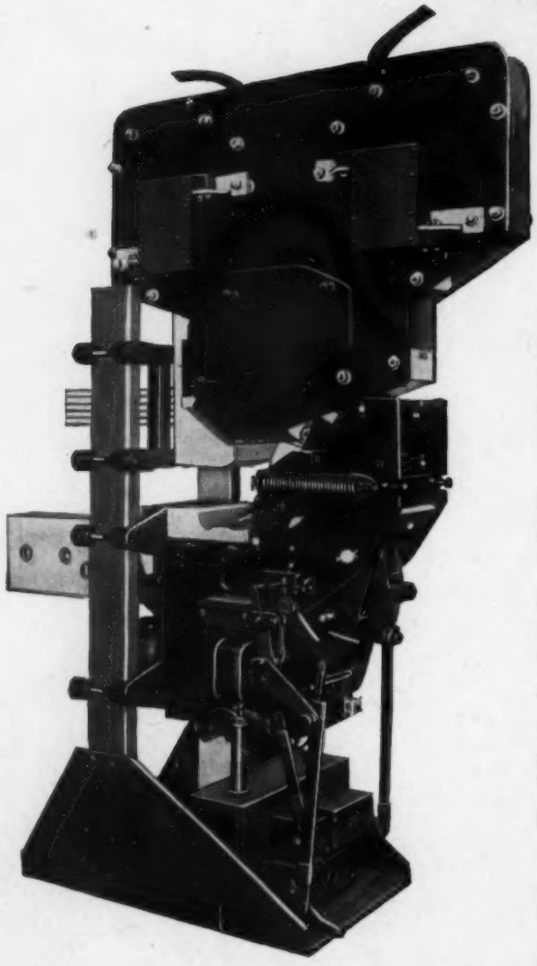


BLOOM ENGINEERING CO.

857 W. North Avenue Pittsburgh 12, Pa.

Life Expectancy

INSURED



. . . with MT Circuit Breakers

Production men know they must get the most from their motors, and maintenance realizes they must accurately determine motor life expectancy to do this. However, if the motors are not safeguarded by adequate protective devices, neither they nor associated equipment will ever attain their life expectancy. Overloads and short circuits will considerably shorten the useful service period.

When applied to electrical equipment in steel mills, the MT Circuit Breaker "insures" generators, motors, heavy current feeders, rectifiers and synchronous converters against damage caused by electrical faults.

Type MT Circuit Breakers are designed for semi-high speed interruption in circuits where both the load and potential short circuit currents are high. The tripping devices are direct acting and instantaneous. "Rate of Rise" overcurrent trip distinguishes between overcurrent conditions caused by a short circuit or overload and a useful load of high value. Type MT is electrically and mechanically trip-free throughout closing stroke on overload, making it impossible to close on a fault. There is an I-T-E Switchgear Specialist in your neighborhood who will be glad to give you complete details. Use him—at no obligation.

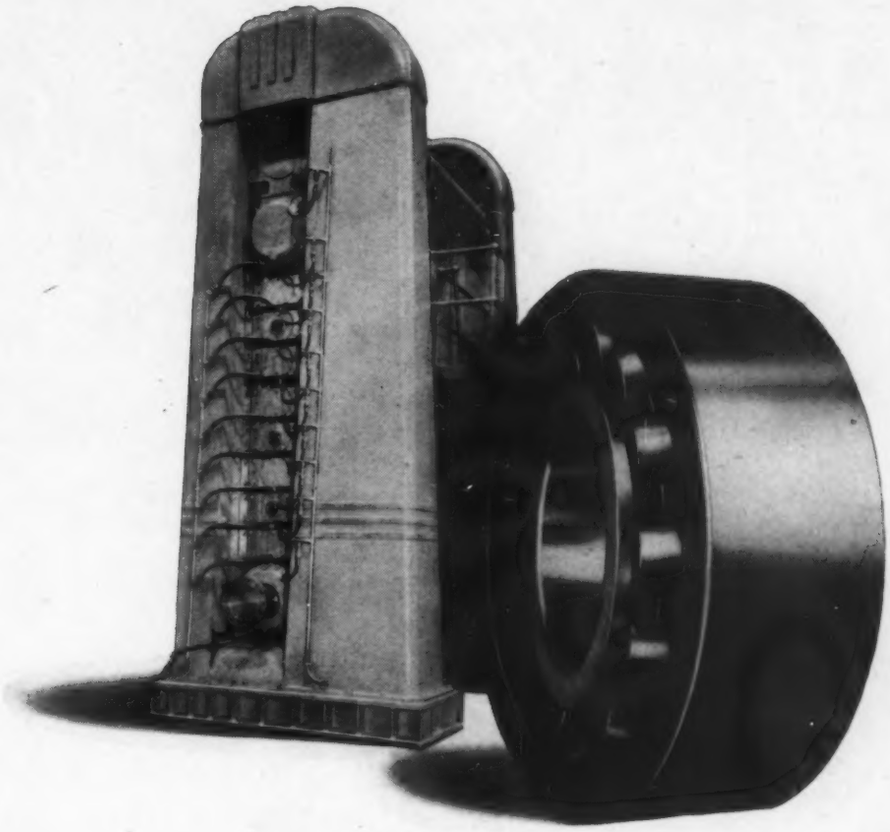
I-T-E Circuit Breaker Company

19th and HAMILTON STREETS • PHILADELPHIA 30, PA.

The rated interrupting capacity is 150,000 amperes in capacities 2,000 and 4,000, and 250,000 amperes in capacities 6,000 and above.

The center of Switchgear Progress

Switchgear • Unit Substations • Bus Structures • Automatic Reclosing Circuit Breakers • High Speed Circuit Breakers • Resistors • Stainless Steel Fabrication



You can stack up massive loads . . .

on intermediate rolls of paper supercalenders and other heavy-duty machines—and secure more efficient operation, longer service life, reduced maintenance and power costs—by carrying radial and thrust loads

On Torrington Spherical Roller Bearings.

Among the many features which assure consistent top performance are self-alignment, high radial capacity and two-directional thrust capacity. Even under conditions of shaft deflection or housing distortion, Spherical Roller Bearings continue to operate at full rated capacity.

To see how these advantages will "stack up" against your design problems, write today for Spherical Roller Bearing Bulletin No. 200-A.

THE TORRINGTON COMPANY

SOUTH BEND 21, INDIANA TORRINGTON, CONN.

Offices in All Principal Cities

TORRINGTON BEARINGS

• NEEDLE • SPHERICAL ROLLER • STRAIGHT ROLLER • TAPERED ROLLER • BALL •

(*Continued from page 129*)

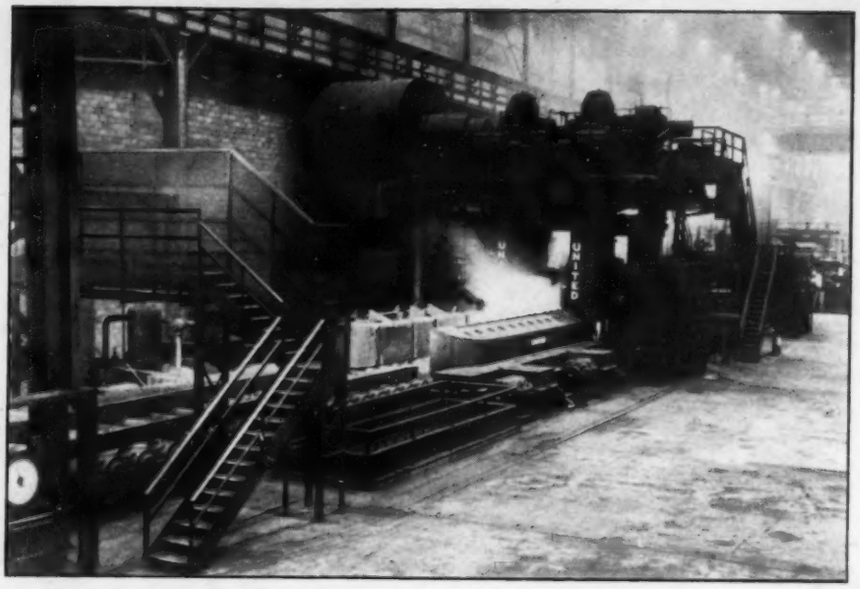
gheny Industrial Electrical Company.

By setting a precise schedule following detailed advance preparation the electrical contractor will remove the old board and install and set in operation a new switchboard during the normal weekend production shutdown.

The switchboard to be replaced now controls three slab reheating furnaces to be remodeled at the Irvin works' 80 in. strip mill. Increased heating capacity of the remodeled furnaces requires the new board.

Rust Furnace Company awarded the sub-contract for the electrical work.

REVERSING SLABBING MILL SHATTERS ALL RECORDS

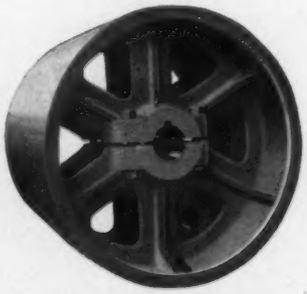


The mill produces slabs up to 20 in. thick in widths to 62 in. from huge ingots weighing as much as 60,000 lb.

▲ The new 45 in. reversing slabbing mill, which recently shattered all previous world's records by producing 159,792 tons of steel slabs in one month in the Homestead, Pennsylvania, plant of Carnegie-Illinois Steel Corporation, is one of the largest mills of its kind in the world.

Designed and built by United Engineering and Foundry Company to help meet urgent steel requirements during the war, it has rolled, since it began operating in January 1944, more than four and a quarter million tons. The mill produces slabs up to 20 in. thick in widths to 62 in. from huge ingots weighing as much as 60,000 lb. The slabs are rolled into thinner steel products such as plates, sheets and tin plate. This mill's record one month output of 159,792 tons

Completely split pulley



Extra heavy conveyor pulley

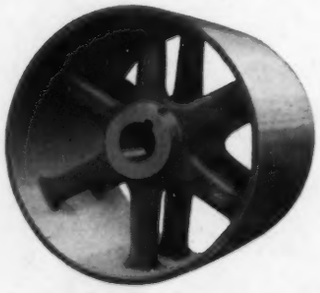
High test cast iron pulleys in all sizes and types

JONES cast iron pulleys are true running — they permit higher speeds — no bushings and they can't fall apart — they don't rattle and they look better on most machines.

These pulleys are machine molded, poured of high test cast iron, and are accurately finished and balanced. Multiple piece pulleys, rubber covered pulleys and flywheels can be furnished.

W. A. JONES FOUNDRY & MACHINE CO.
4131 Roosevelt Road, Chicago, Illinois

Single arm solid pulley



Double arm pulley

Jones

HERRINGBONE — WORM — SPUR — GEAR SPEED REDUCERS • PULLEYS
CUT AND MOLDED TOOTH GEARS • V-BELT SHEAVES • ANTI-FRICTION
PILLOW BLOCKS • FRICTION CLUTCHES • TRANSMISSION APPLIANCES

would provide enough sheet steel for 175,000 automobiles.

The mill's horizontal rolls are 45 in. in diameter by 80 in. long and are driven by two 5000 hp motors. It is the first primary mill of its type on which roller bearings have been used.

STEEL SHIPMENTS REACH NEW PEACETIME PEAKS

▲ Latest reports covering shipments of steel to consuming industries in the first four months of 1947 reflect the record high peacetime production of the steel industry early this year, according to the American Iron and Steel Institute. The total amount of steel shipped to consumers was 20,447,827 tons. The classification, jobbers, dealers and distributors, received the largest aggregate amount, 3,461,794 tons, 16.9 per cent of the total shipped, for distribution to thousands of small users of steel.

In the first four months of 1947, the automotive industry received 2,984,749 tons of finished steel products, an improvement of 14 per cent over the total shipped during the preceding four months. Shipments to freight car builders during the first four months of 1947 at 686,553 tons, equivalent to the amount needed for approximately 31,000 new domestic cars, showed an 18 per cent gain over the total steel received by this group in the previous four months. Finished steel shipments destined for the oil and natural gas industry during the early months of 1947 were one-third larger than during the final four months of 1946. The amount of steel shipped directly for export was 7.0 per cent of the total steel shipments in the first four months of this year.

The automotive industry received 14.6 per cent of the total steel shipped, slightly better than its share of shipments in 1941. Construction received 9.6 per cent of total steel, 8.0 per cent went to steel for converting and processing, while rail transportation took 7.9 per cent, machinery manufactur-

(*Please turn to page 136*)

BEARING DEMAND ABOVE PRE-WAR PRODUCING LEVEL

With demand for anti-friction bearings up two to five times above prewar levels, SKF Industries, Inc., is spending $4,000,000 to expand and modernize its two Philadelphia plants. Primary aim of program is to increase output of spherical roller bearings, of which this firm is nation's largest single producer. Scene in plant shows workers assembling largest spherical roller bearings ever made in the U. S. They will go into a new Wisconsin paper mill.

BUT . . .

It could never meet the demands of modern commerce. Today's huge, high-speed, coast to coast trailer trucks, exemplify America's general all around progress, since the days of the pioneer. And—so it is with

CHEMICALS ACP PROCESSES

RUST PROOFING AND PAINT BONDING
Granodine *
Duridine *
Alodine *
Lithoform *
Thermoil-Granodine *

RUST REMOVING AND PREVENTING
Deoxidine *
Peroline *

PICKLING ACID INHIBITORS
Rodine *

Rodine*

RODINE is particularly typical of American scientific progress. It saves good metal—prolongs the life of the pickling bath—kills unpleasant and destructive fumes, and assures better control in sulfuric and muriatic acid pickling. Over-pickling and accompanying acid embrittlement are held to a minimum.

There's a type of RODINE for your own pickling job. Your inquiries are welcome.

* Trade Mark Reg. U. S. Pat. Off.

AMERICAN CHEMICAL PAINT CO.
AMBLER ACP PENNA.

Bring on Your Tube Cutoff Problems!

ETNA

Tube Cutoff Machine

THE TUBE REMAINS STATIONARY . . . .

IT'S THE CUTTER HEAD THAT ROTATES

•

The entire cutoff cycle—clamping of tube, cutting off and unclamping is completely automatic.

SINGLE PUSHBUTTON CONTROLLED

What are you doing about tube cutting

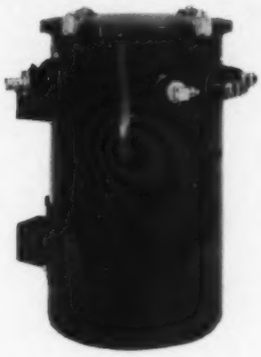
?

THE ETNA MACHINE CO., 3404 Maplewood Ave., TOLEDO 10, OHIO

Pennsylvania
... an important name in transformers

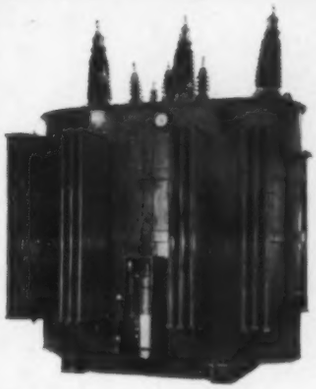
It's a fact that Pennsylvania Transformers are making friends all over the country by giving good, honest service. We believe one of the major reasons for this is the special emphasis placed by Pennsylvania on research and development work, which has resulted in the introduction of many important improvements, such as the Straight Line Tap Changer, Uni-Row Radiators, and Precompressed Coils.

If you are in the market for transformers, you'll do well to consider Pennsylvania. The Pennsylvania Representative nearest you will be glad to review your transformer problems and discuss Pennsylvania's complete line of Distribution and Power Transformers.



3 Kva. Typical through 25 Kva.

DISTRIBUTION
3 Kva to 500 Kva. Up to 66,000 volts.

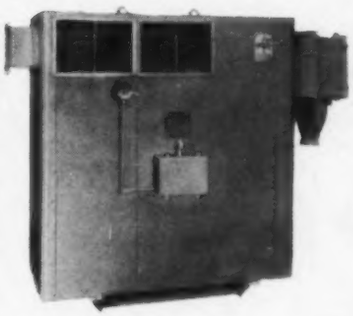


7500 Kva, 3 Phase, 60 Cycles 115,000-34,500/19,900 volts.

POWER
667 Kva to 50000 Kva. Up to 165,000 volts.

15,000 Kva with motor operated tap changer.

FURNACE
Up to 20,000 Kva

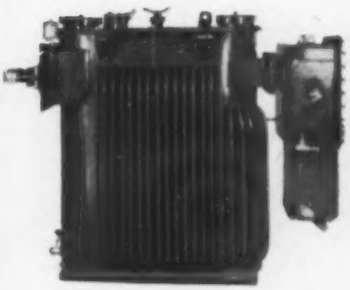


1000 Kva, 3 Phase, 60 Cycles 12,000-480 volts.

DRY TYPE
Natural and Forced Air Cooled.

3000 Kva, 3 Phase, 25 Cycles 13,800-480 volts.

ASKAREL
Distribution and Power sizes.



450 Kva, 3 Phase 22,000-208 volts.

NETWORK
Indoor or street vault installation.

WRITE FOR FREE COPIES
of our eight page booklets, "4 Minutes with Pennsylvania Transformers", "Ask for Askarel".

Pennsylvania
TRANSFORMER COMPANY
PITTSBURGH, PENNSYLVANIA

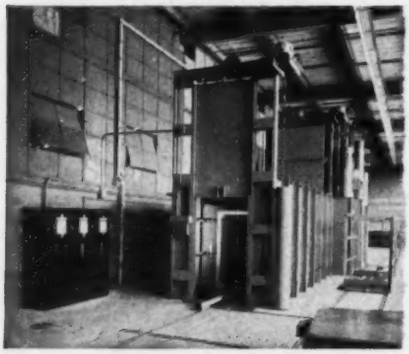
Pennsylvania TRANSFORMERS

R-S Furnace Facts

FOR THOSE CONCERNED WITH QUALITY HEATING OF METALS

2 ROOMS AND BATH...

Here is a highly efficient R-S electric batch type furnace for treating aluminum aircraft parts at Republic Aviation, Farmingdale, L. I., New York.



This can be run as a single chamber if desired but becomes a 2-room furnace when you drop the middle lift door. Each chamber has a circulating fan. In normal operation the loaded racks are moved by conveyor chain beneath the floor into the high temperature chamber. After treatment a limit switch opens an intermediate door, starts the conveyor motor and a circulating pump in the quench chamber adjoining the furnace at the nearer end in the pic (door open). The parts are moved quickly into the quench chamber. After quenching they are moved slowly to the outside track and around to the low temperature chamber at the far end of the furnace for aging.

JMLco PH-1

A heat-treating plant in Bellaire
Found maintenance causing despair
When they bought an R-S
You can easily guess
Their troubles dispersed in the air.

It is clear that the longer you plan to keep a thing—such as a furnace, a capital investment—the more important maintenance becomes, and the less important the first cost. A policy of buying always at minimum bid figures must inevitably lead to high maintenance figures. The figures of the A.I.S.E. show that Maintenance in the Steel industry is 3 times Profits.

That's an Equation, Son!

But it ceases to be an equation in any plant where R-S Furnaces do the work. Furnaces that run for YEARS at a minimum expenditure for upkeep are a handsome investment because they add directly to operating profit.

FURNACE DIVISION
R-S Products Corp.
PHILADELPHIA 44, PA.

(*Continued from page 133*)

ers received 5.3 per cent, and contractors' products accounted for 3.7 per cent of total shipments, electrical machinery and apparatus consumed 2.6 per cent, appliances, utensils and cutlery received 2.5 per cent, and other domestic and commercial equipment accounted for 2.8 per cent.

In the first four months of 1947, sheet and strip shipments to the auto industry totaled 1,856,815 tons. The auto industry's share of sheet and strip shipments amounted to 31.3 per cent of total tonnage shipped, as against 27.8 per cent in 1946.

Shipments of finished steel to freight car builders during the first four months of 1947 amounted to 686,553 tons, an 18 per cent gain over the 583,219 tons received by this group during the last four months of 1946.

WESTINGHOUSE BUILDS NEW MILL MOTOR LINE

▲ A new line of mill motors reduced one frame size is announced by Westinghouse Eectric Corporation. A larger and more efficient armature that fits within the limiting dimensions of the motor frame, new roller bearings and bearing housing, and redesigned field coils make the new motor possible.

The heavy duty type MC mill motor is available in totally enclosed, protected self-ventilated or protected force-ventilated construction. It is built in accordance with the AISE standardized dimensions and incorporates the following features: split frame of cast steel; silicone insulated armature coil conductors; wedges of Class B material to hold coils in slots; new roller bearing and bearing housing that eliminates need of thrust washer and collars; improved field coil insulation; and rigid mounting of brush holders.

It is available in sizes from 5 to 200 hp; in voltages of 230 and 550; and in AISE dimension frames 602 to 618.

The new mill motor is in accordance with AISE standardized dimensions.

WAR SURPLUS FURNACES AVAILABLE AT LOW COST

▲ Nearly $43,000,000 worth of surplus heat-treating furnaces and ovens are being offered for sale by War Assets Administration at fixed prices ranging from 36 to 75 per cent of acquisition cost.

Built by the government for war purposes at costs of $500 to $250,000 each, the equipment includes foundation and portable type furnaces for heat-treating metals and heating and reheating specialties as well as ovens for enameling, japanning and lacquering.

In line with a new disposal program, industries will have an opportunity to state their specifications to WAA for such equipment, and inventories will be screened for types of furnaces or ovens which will fit the needs of the customer.

The low fixed prices will allow purchasers to modify or rebuild the equipment for their own purposes. Those furnaces and ovens which are in need of major overhauling will be offered on a competitive bid basis.

Principal inventories are held by the following WAA Regional Offices: Boston, Chicago, Cincinnati, Cleveland, Detroit, New York, Philadelphia, Richmond, St. Louis, Kansas City, Grand Prairie and Birmingham.

RUST BUILDS FURNACE AT SPANG-CHALFANT

▲ A new bloom heating furnace with a capacity of 100 tons an hour will be constructed for Spang-Chalfant division of National Supply Company at Ambridge, Pennsylvania, by Rust Furnace Company.

The furnace, one of the largest ever to be built for a tube mill, will have an effective heating length of 97 ft. It will be triple-fired, zone controlled, end charged and end discharged.

A brick lined stack to serve the

furnace also will be built. The chimney will be 150 ft high with an interior diameter of 7 ft 6 in.

STAINLESS STEEL TEST RESULTS ARE AVAILABLE

▲ Several distinct advantages are offered by electrolytic manganese over commercial low-carbon ferromanganese in the manufacture of some stainless steels, an Ohio company reported to the Bureau of Mines following a series of tests in the making of five types of stainless steels, Dr. R. R. Sayers, director of the bureau, announced recently.

These conclusions were based on the results of 81 full-scale commercial heats of basic electric steel at the Timken Roller Bearing Company of Canton, Ohio, where electrolytic manganese prepared from domestic ores under a process developed by the Bureau was used in place of commercial ferromanganese, Dr. Sayers said.

In using the pure metal at the Ohio plant, a report now being distributed by the Bureau discloses that the average manganese recovery is slightly higher; the absence of carbon in electrolytic manganese is a distinct advantage in melting 18-10-plus columbium types; electrolytic manganese is easier to handle and store; and additions to the furnace can be calculated and weighed more accurately when the pure metal is used. No difference was noted, however, in hot-workability, surface condition, or performance of the steel.

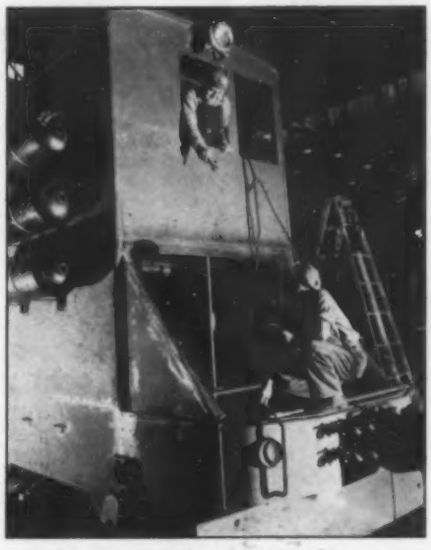
More than 50,000 pounds of electrolytic manganese prepared in the Bureau's pilot plant at Boulder City, Nevada, were used in the 81 commercial heats.

The Bureau report, based on data and observations of officials of the Timken Roller Bearing Company, was prepared by F. Sillers, Jr., and R. T. C. Rasmussen, Bureau metallurgists.

A free copy of the publication, Report of Investigations 4078, "Electrolytic Manganese in Stainless Steel; Tests at the Timken Roller Bearing Company, Canton, Ohio," may be obtained by writing to the Bureau of Mines, Department of the Interior, Washington 25, D. C.

20-TON LOCOMOTIVE FOR STEEL PLANT SERVICE

Used for coke-quenching car service, this 20 ton, 2 axle, 250 volt electric locomotive, nearing completion, is about 15 ft high and only 20 ft long. Rated at 10,000 lb starting tractive effort, this unique unit has a top speed of 7.5 mph. The locomotive is being constructed in the locomotive shops of the General Electric Company.

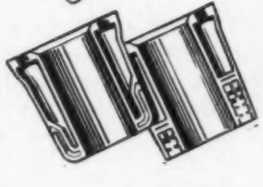


Another CONTRIBUTION

THE HOLZWORTH "SPLIT-NOSE" Tuyere — U. S. Patent 1,789,870 — is giving great satisfaction to blast furnace operators because it CAN TAKE IT in these days of bad coke. It can stand up longer, consequently tuyere costs are lower. This is due to the fact that its design forces a continuous down air blast, thereby eliminating air eddies that allow pools of molten metal to accumulate and burn your tuyeres.

We can serve you promptly, as we have the exclusive license to make and sell this tuyere.

Makers and distributors of Falcon "ANCHORLESS" Cooling Plates, Hot Blast Valves and Seats, Monkeys, the following special tuyeres: Butler-Henry Heavy Nose, Falcon Shrouded, Beaton-Ledbetter, Fleisch Safety, Kinney Heart-Shaped, Steinbacher Angle Flow and Beaton Refractory Nose.



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FALCON BRONZE CO.

YOUNGSTOWN 3, OHIO

Established 1890 - Incorporated 1895

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Contains a wealth of Valuable Data on PREVENTIVE MAINTENANCE of Commutators and Slip Rings

Make sure your files contain a copy of this handy reference guide—for all sizes of motors and generators. It illustrates and describes the latest methods and equipment for commutator and slip ring maintenance, including Ideal Resurfacers, Cleaning Stones, Brush Seaters, Undercutters, etc. Write now for your copy of this Free Book!

IDEAL

IDEAL INDUSTRIES, Inc.

Successor to Ideal Commutator Dresser Co.

1045 Park Avenue — Sycamore, Illinois

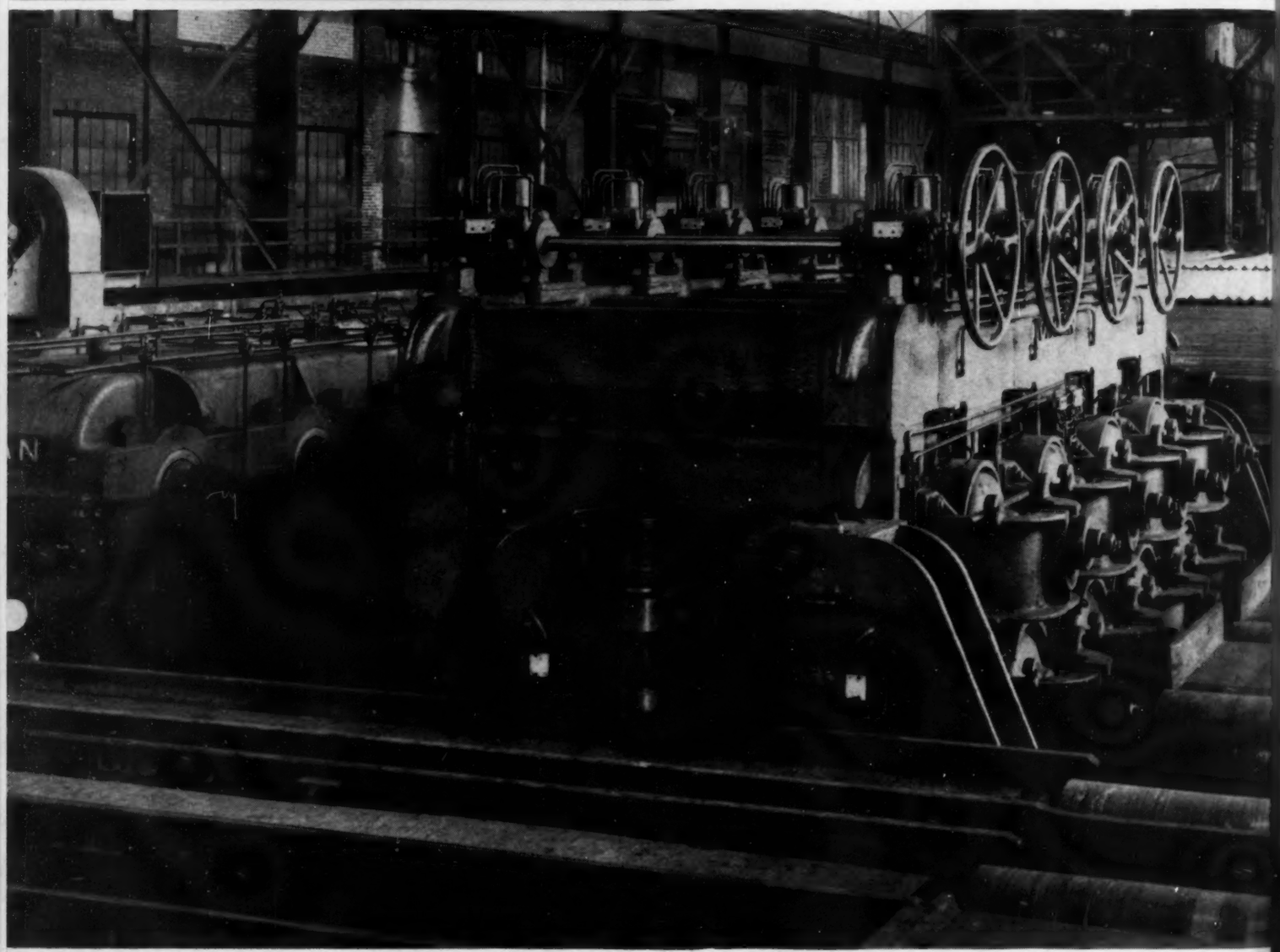
24" I BEAM STRAIGHTENER

BUILT BY MORGAN Engineering

Illustrated is a Morgan Roller Straightener for structural shapes up to 24" I beams.

It is equipped with four top and four bottom rolls, all of which are adjustable. These eight rolls are arranged to be connected by spindles to a separate enclosed gear box drive. All gear shafts are mounted in roller bearings. Vertical rolls are provided on both entry and delivery sides.

A section of roller table is mounted on one side of straightener to be shifted into the roller table line when straightener is not in use.



THE MORGAN ENGINEERING CO.
ALLIANCE, OHIO
Pittsburgh 1420 Oliver Building

DESIGNERS • MANUFACTURERS • CONTRACTORS
BLOOMING MILLS • PLATE MILLS • STRUCTURAL MILLS • ELECTRIC TRAVELING CRANES • CHARGING MACHINES • INGOT STRIPPING MACHINES • SOAKING PIT CRANES • ELECTRIC WELDED FABRICATION • LADLE CRANES • STEAM HAMMERS • STEAM HYDRAULIC FORGING PRESSES • SPECIAL MACHINERY FOR STEEL MILLS

Personnel News . . . .

Roy L. Leventry has retired from active management of Republic Steel Corporation's Youngstown district but will remain with Republic as a consultant and will maintain offices in Youngstown. Mr. Leventry has been with Republic Steel and its predecessor company, Republic Iron and Steel, since 1918, when he came to Youngstown as superintendent of Republic's open hearth furnaces. Three months later he became general superintendent of the steel plant and later assistant district manager. In 1937 he was appointed manager of Republic's Youngstown district.

A native of Johnstown, Pennsylvania, he was born in 1888. He attended high school in Johnstown and Cornell University. During his student days he attained prominence as an athlete, specializing in football and track. After graduation from college he worked for a period for the Grand Crossing Tack Company in Chicago, until recently a part of Republic Steel. Later he returned to Johnstown and went to work as a laborer for the Cambria Steel Company. He advanced rapidly and was assistant superintendent of open hearth furnaces at the time he left Cambria to come to Youngstown. He is well known throughout the nation among steel men and regarded with high esteem by his many associates.

J. H. Graft was made manager of Republic Steel Corporation's Youngstown district. Mr. Graft was born in Connellsville, Pennsylvania, where he graduated from high school. For three years he was with the West Penn Power Company and spent an equal length of time at the Standard mines of the H. C. Frick Coke Company. He then became associated with the Youngstown Sheet and Tube Company, Campbell works, and for seven years was assistant electrical superintendent. Early in 1936 he joined Republic Steel as superintendent of the electrical department of the Youngstown district. Late in 1939 he was made assistant district manager at Warren and returned to Youngstown as assistant manager of that district in 1940. He was made assistant district manager of the Buffalo district in May, 1943.

Laurence S. Dahl, general superintendent of Carnegie-Illinois Steel Corporation's Irvin works since 1940, has been appointed general superintendent of this U. S. Steel subsidiary's Youngstown district succeeding A. C. Cummins, deceased.

A native of Kennedy, Minnesota, Mr. Dahl attended Interstate College in Fargo, North Dakota. He was first employed by U. S. Steel in 1924 at the Gary works in Gary, Indiana. He served in increasingly responsible positions in various sheet and tin mill operations at the Gary plant and when the Irvin works was constructed in 1937 he was chosen as its first assistant general superintendent.

H. D. Stark, formerly general superintendent of the Pittsburgh works of Jones and Laughlin Steel Corporation, has been appointed assistant general manager of manufacturing operations. Mr. Stark went to work for Jones and Laughlin Steel Corporation in 1899 as a blueprint boy in the engineering department of the South Side works and has successively occupied positions as superintendent of shops, assistant superintendent of the steel works, superintendent of the steel works, assistant general superintendent of the South Side works and assistant general superintendent of the Pittsburgh works. In February, 1936, he was appointed general superintendent of the Pittsburgh works.

A. T. Lawson, formerly chief industrial engineer of the Jones and Laughlin Steel Corporation, was made general superintendent of the Pittsburgh works. Mr. Lawson was associated with Jones and Laughlin for 30 years, having started with the company in 1916 at its Pittsburgh works' engineering department. From 1930 to 1946 he was in charge of the industrial engineering department at the Aliquippa, Pennsylvania, works. In November, 1946, he was appointed chief industrial engineer.

W. L. Witney, formerly assistant chief industrial engineer for Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania, has been promoted to chief industrial engineer.

J. H. Slater was raised to senior assistant district manager of the Cleveland district of Republic Steel Corporation. Mr. Slater was appointed assistant district manager of Republic's Cleveland district in 1940 and was acting district manager while **J. L. Hyland,** district manager, was on assignment for the United States government in Europe. He is well known in the steel industry as an authority on blast furnace operation.

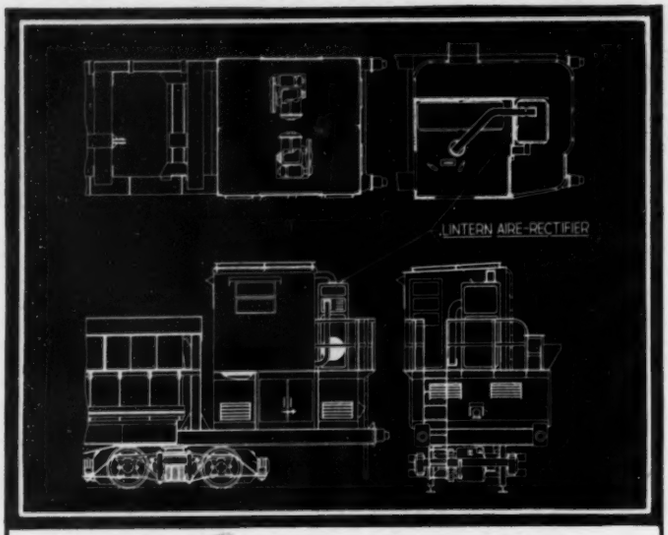
M. D. Wald was made assistant district manager of Republic Steel Corporation's Cleveland district. Mr.

ROY L. LEVENTRY

J. H. GRAFT

LAURENCE S. DAHL

H. D. STARK



16

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Wald was born in Lithuania and came to the United States as an infant. He went to grammar and high schools in Chicago and graduated as a mechanical engineer from the Armour Institute of Technology in 1913. He joined the organization of the Inland Steel Company and worked as a foreman in the coke works until 1916 when he came to Cleveland to become assistant superintendent of the coke plant at the Corrigan-McKinney Steel Company, now Republic's Cleveland steel plant. He was made superintendent of the coke plant in 1918 and in 1934 was made superintendent of blast furnaces and coke plant. In May, 1943 he was appointed assistant district manager of Republic's Warren district.

Harry L. Allen, Jr., open hearth superintendent and acting assistant manager, Cleveland district, Republic Steel Corporation, was made assistant district manager, Buffalo district. Mr. Allen went to work for Corrigan-McKinney Steel Company in 1933 and continued with Republic after the merger in 1935. He occupied various positions in the metallurgical and inspection departments, and in 1943 was made open hearth superintendent. He held the position of acting assistant district manager while Mr. Hyland was in Europe. He is a native of Cleveland, attended East High School, Case Institute of Technology, and University of Alabama.

John H. Elliott has been raised to general superintendent of Carnegie-Illinois Steel Corporation's Irvin works. Mr. Elliott succeeds L. S. Dahl, appointed general superintendent, Youngstown district.

Born in Elwood, Indiana, Mr. Elliott attended the University of Pittsburgh where he studied engineering. He started with U. S. Steel in 1919 in the engineering department of the American Sheet and Tin Plate Company in Pittsburgh. In 1926 he was transferred to the Shenango works as combustion engineer and was promoted through various departments in that plant to the post of assistant superintendent early in 1937.

JOHN H. ELLIOTT

Later that year he was transferred to the newly constructed Irvin works as superintendent of the tin finishing division. In 1939 he was made assistant to the general superintendent and in May 1940 became assistant general superintendent, the position held at the time of his present appointment.

P. P. Echols was moved from special metallurgical duties to assistant to the district manager at Republic Steel Corporation's Warren district. Mr. Echols came to Republic in 1935 as chief metallurgist in the Warren

district. Previously he had been employed by the Bethlehem Steel Company and the Weirton Steel Company. In 1940 he was transferred to the Cleveland district and in February, 1945, returned to metallurgical duties at Warren.

H. J. Walker was promoted from open hearth superintendent to general superintendent of the steel works, from coke plant to blooming mill inclusive, Warren district of Republic Steel Corporation. Mr. Walker came to the Trumbull Steel Company, a Republic predecessor company, in 1928, as a first helper in the open hearth department. Previously he had been employed by the Brier Hill Steel Company. In 1930 he was promoted to melter, and in 1938 was made superintendent of the open hearth department.

Charles D. Mills has been appointed assistant to manager of operations, Pittsburgh district of U. S. Steel's Carnegie-Illinois Steel Corporation. Mr. Mills was born in Jamaica, Long Island, New York, and is a

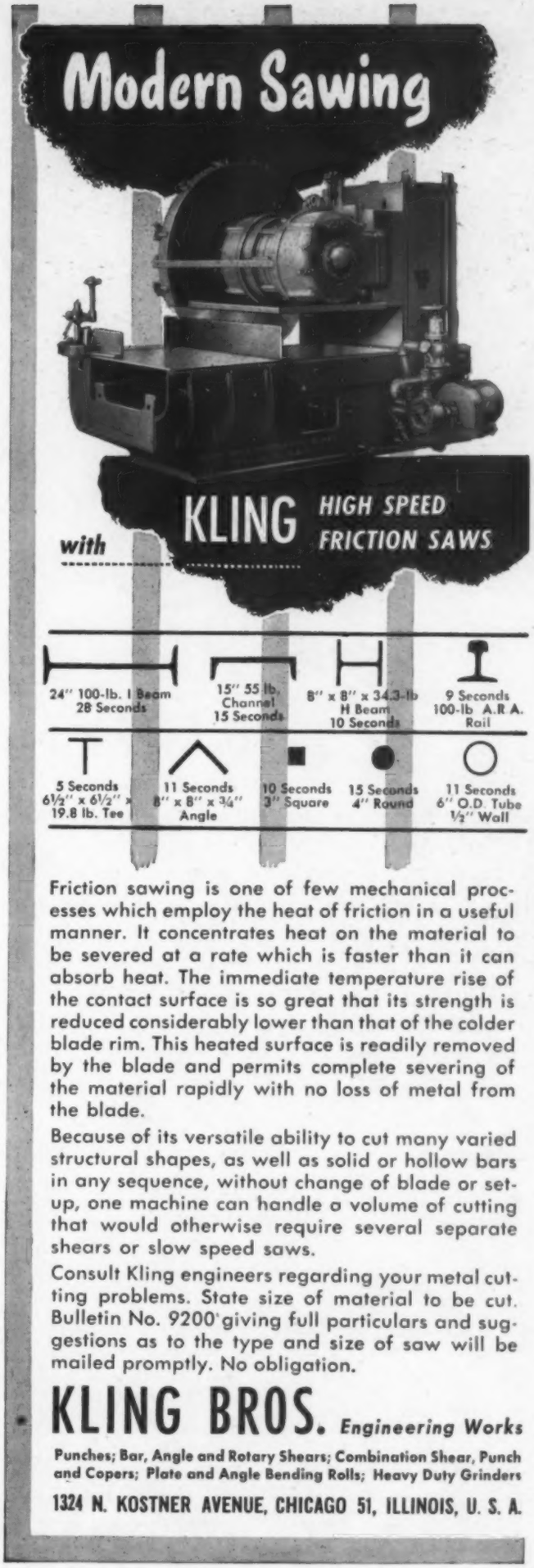
CHARLES D. MILLS

graduate of Carnegie Institute of Technology where he received a degree in civil engineering in 1919. He started with U. S. Steel that same year in the engineering department of New Castle works. He was transferred to Pittsburgh general offices in 1932 as specialty engineer and in 1941 was made manager — raw materials, fuel and power division, Pittsburgh district, the position he held at the time of his present appointment.

Earl W. Mahaney, former metallurgist for Youngstown Sheet and Tube Company at Youngstown, Ohio, has been appointed assistant general superintendent of the company's strip and tin plate division at Indiana Harbor, Indiana.

Mr. Mahaney, a graduate of West Virginia University, joined Youngstown Sheet and Tube Company in 1936 as a metallurgical observer. After considerable experience in the Campbell laboratory, bloomer, seamless tube and open hearth department, he was transferred to the company's Brier Hill works at Youngstown and later appointed a metallurgist. Last year he was transferred to general offices as an associate of **Dr. Karl L. Fetters,** special metallurgist.

C. H. Murray, vice president of American Rolling Mill Company, has been appointed by the United States Department of Labor as a principal delegate represent-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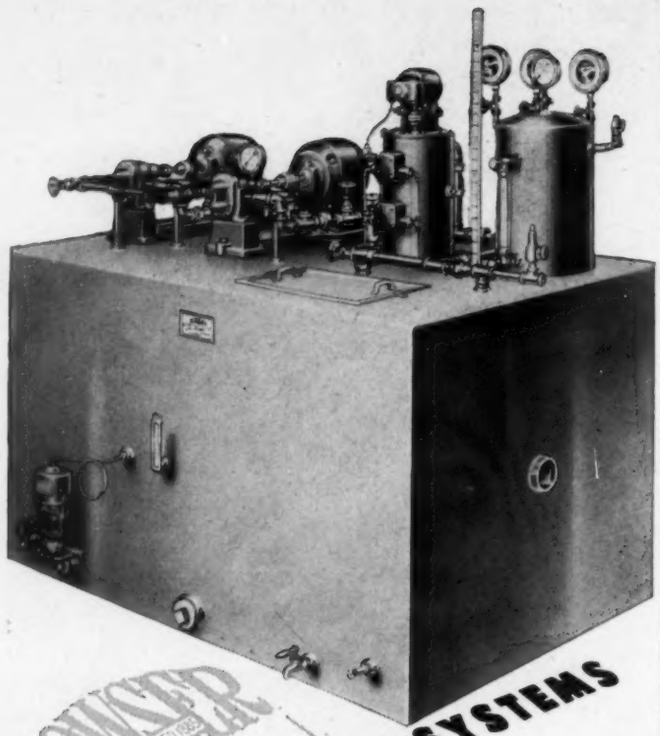

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ing the iron and steel industry at the International Labor Conference in Stockholm, Sweden, from August 19 to September 21, 1947. He sailed for Sweden on the Queen Mary on August 8. Mr. Murray was recommended by the board of directors of the American Iron and Steel Institute and President Earl Shreve of the United States Chamber of Commerce to serve as one of the two employer representatives at the Iron and Steel session of the International Labor Organization.

Arno L. Billeter has been appointed assistant general superintendent of Carnegie-Illinois Steel Corporation's Irvin works.

Mr. Billeter, a Missourian by birth, attended Kirks-

ARNO L. BILLETER

ville State Teachers College and Colorado State University. He was first employed by U. S. Steel in 1919 as foreman in the annealing department of Gary sheet mill at Gary, Indiana. In 1937 he was transferred to the Irvin works as superintendent of the cold reduction department. In April 1941, he was made assistant to the general superintendent and three years later was promoted to superintendent of the Vandergrift plant, the position he held at the time of his present appointment.

Albert J. Berdis will succeed Mr. Billeter as superintendent of Carnegie-Illinois Steel Corporation's Vandergrift plant of Irvin works.

Mr. Berdis, a native of Whiting, Indiana, is a gradu-

ALBERT J. BERDIS

ate of Purdue University where he received a bachelor of science degree in electrical engineering. He started with U. S. Steel in 1929 as a fuel engineer at Gary works, Gary, Indiana. In 1935 he was transferred to Pittsburgh general offices as electrical engineer and in 1938 was made appropriation control engineer at Irvin works. He was promoted in 1945 to assistant to the general superintendent, the position he leaves to fill his new assignment.

W. F. Rochow was promoted to the position of assistant to the president of Harbison-Walker Refractories Company. In his new position, Mr. Rochow will be in charge of the research and sales technical departments.

Mr. Rochow has been with Harbison-Walker since his graduation from Pennsylvania State College, department of chemical engineering in 1912. His work has been with both departments he now heads. Early work in the research department included the taking out of basic patents on high temperature cements. The manufacture of these today represents a sizable industry. In the sales technical department, his interests have been directed to the proper choice and application of established and newly developed refractories in the many types of industrial furnaces.

Preston M. Postlethwaite has been appointed manager of both electrical and automotive divisions of the Wagner Electric Corporation branch at Portland, Oregon. This transfer follows his association with the sales department of the Wagner branch at Pittsburgh. In his new position, Mr. Postlethwaite will direct the operation of the Portland branch and the distribution and merchandising of Wagner automotive and electrical products in this territory.

Richard M. Paxton, Jr. has been elected a vice president of the Jessop Steel Company, Washington, Pennsylvania. Mr. Paxton joined the Jessop Steel Company in 1924 and has served in various capacities in all of the company's production departments and laboratories. In March 1927, he was transferred to New York City, where for the past twenty years he has been in charge of Jessop's New York branch office.

A graduate of Cornell University, Mr. Paxton also studied metallurgy at the Carnegie Institute of Technology.

R. W. Kise has been named manager of sales of General Electric Company's industrial heaters and devices section. Mr. Kise joined General Electric in 1930. After completing the company's business training course he was assigned to advertising and sales promotion work. In 1940 he became a sales and application engineer in the industrial heating division, a position he held until his new assignment.

John R. Gregory, of San Mateo, California, was made Blaw-Knox Company's Pacific Coast representative for steel plant sales. Mr. Gregory has had many years' experience in the steel sales field.

James W. Kinnear, Jr. was made executive vice president of the Firth Sterling Steel and Carbide Corporation. Mr. Kinnear has resigned his position of assistant manager of operations of the Pittsburgh district of the Carnegie-Illinois Steel Corporation to accept the new position.

Mr. Kinnear is a graduate of Allegheny College and

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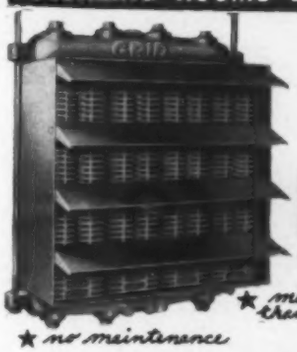

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also of Massachusetts Institute of Technology. He started with the Carnegie Steel Company as a laborer in its open hearth department at Homestead steel works in 1923, holding various positions in that plant such as chief metallurgist and assistant general superintendent. In 1940 he was promoted to his present position over all the plants in the Pittsburgh district. During the war years he served on various army and navy committees in connection with the manufacturing of alloy steels and armour plate. He was also a member of the American British committee for the conservation of alloys.

Wilber F. Pray has been announced as New York district manager for Askania Regulator Company. Mr. Pray has been associated with Askania since the inception of the company. The New York district office is located in the General Precision Equipment Corporation Building, 92 Gold Street, New York 11, New York.

Raymond R. Rausch of Detroit has been retained as a consultant to the General Electric Company on manufacturing matters. Mr. Rausch was associated for many years with the Ford Motor Company, at one time having been president of the Henry Ford Trade School and a member of the company's board of directors. Before joining the Ford organization he was general superintendent of the Timken Detroit Axle Company.

E. C. Wright, former assistant to president of National Tube Company at Pittsburgh, Pennsylvania, was recently appointed professor of metallurgical engineering and head of the department of metallurgical engineering at the University of Alabama. Mr. Wright also will be engaged in consulting engineering and research work.

He was with National Tube 21 years, being chief metallurgist of the company's Ellwood City, Pennsyl-

E. C. WRIGHT

vania plant from 1927 to 1936, then chief metallurgist for the entire company for seven years, followed in 1943 by his appointment as assistant to president. He was active in developing apprentice engineering courses and in improving the metallurgical operations of the company.

Before joining National Tube, Mr. Wright had been associate professor of metallurgy at the University of Alabama.

Robert A. Gillies was appointed vice president of the Steel Company of Canada, Ltd., in charge of all manufacturing, with headquarters in Hamilton, Ontario. He is a graduate of Cornell University, Class of 1910. Mr. Gillies gained his early experience in the steel industry with the Illinois Steel Company at their South works. In May 1928 he joined Steel Company of Canada, Ltd. at Hamilton as superintendent of blast furnaces, and prior to his appointment as vice president has successively held the positions of assistant works manager and works manager of the Hamilton works.

R. L. Puette has been elected vice president in charge of production of Clark Controller Company.

A graduate of Case School of Applied Science in

R. L. PUETTE

electrical engineering, he has spent the major part of his business career with Clark, starting in 1930.

He has been manager of the application engineering department, assistant sales manager, sales manager, and works manager.

George Paul Burks was promoted to division superintendent of the blast furnaces at Carnegie-Illinois Steel Corporation's Gary works.

Mr. Burks, a native Hoosier and chemistry graduate of Wabash college in Crawfordsville, has been associated with the steel plant almost continuously for nearly 32 years. He started as a chemist and became chief chemist 10 years ago; and, since 1942, served as assistant superintendent of blast furnaces.

GEORGE PAUL BURKS

Walter Scott MacNabb retired voluntarily, because of ill health, from division superintendent of blast furnaces at Carnegie-Illinois Steel Corporation's Gary works. He had been with the plant since 1907 except for years spent in executive positions with the Indian Iron and Steel Company and the Tata Iron and Steel Company at Jamshedpur, India.

A. L. Sonnhalter, for 15 years vice president in charge of the Pittsburgh Crucible division of Crucible Steel Company of America at Midland, Pennsylvania, has resigned because of ill health. Mr. Sonnhalter will continue as a director of the company, and will serve as advisor and consultant to the management. He has been elected president of the Midland Water Company, a subsidiary of Crucible Steel.

S. J. Moran has been advanced to the position of works manager and **J. L. Daugherty** has been appointed to succeed him in the position of assistant treasurer and production manager for the Union Steel Castings division of Blaw-Knox Company.

Mr. Moran attended night school at Duquesne University. He started at Union Steel Castings as an office boy and has served on nearly every job in the shop and office.

Mr. Daugherty graduated from Grove City College in 1937. A certified public accountant, he was employed by an accounting firm before joining Blaw-Knox in 1941. He served as an accountant with the parent company and then assumed the position of division auditor at Union Steel Castings.

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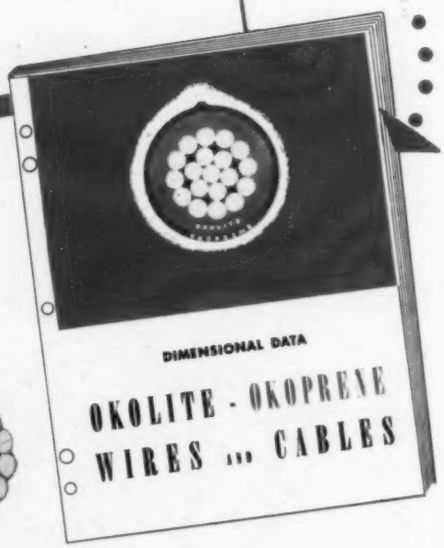

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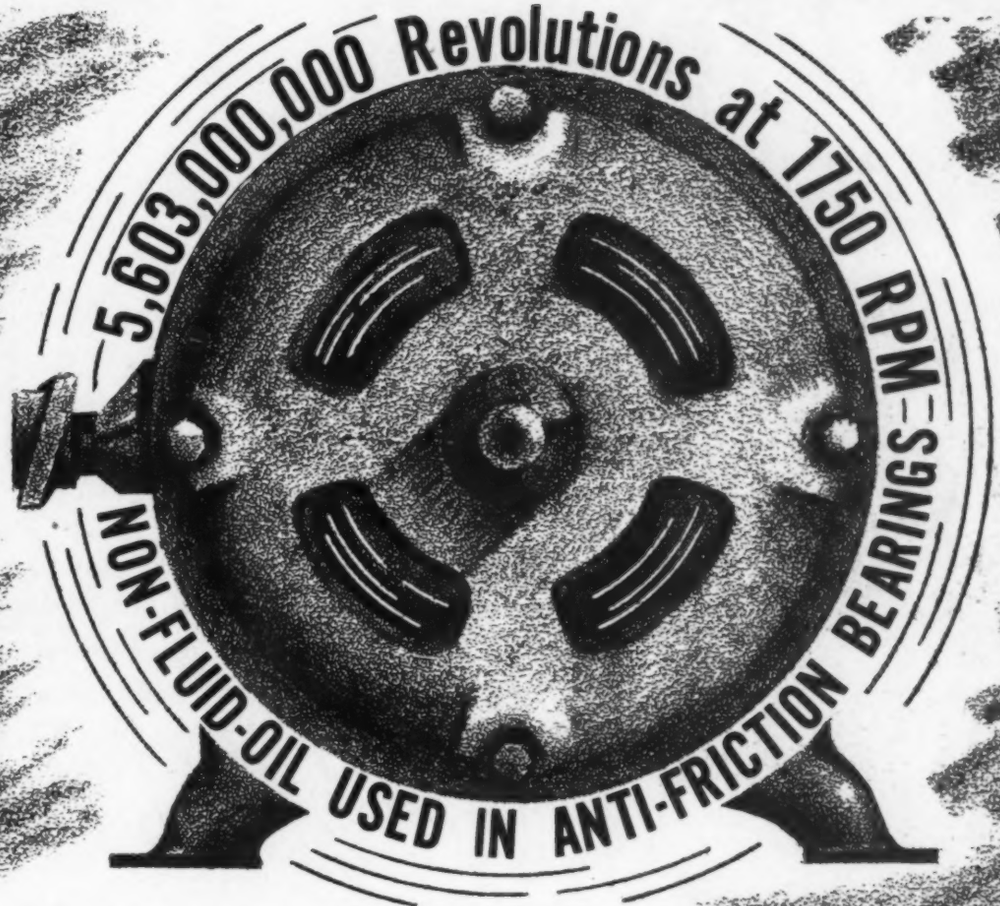

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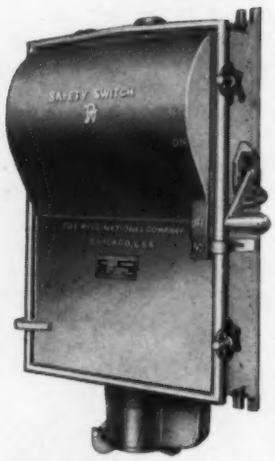

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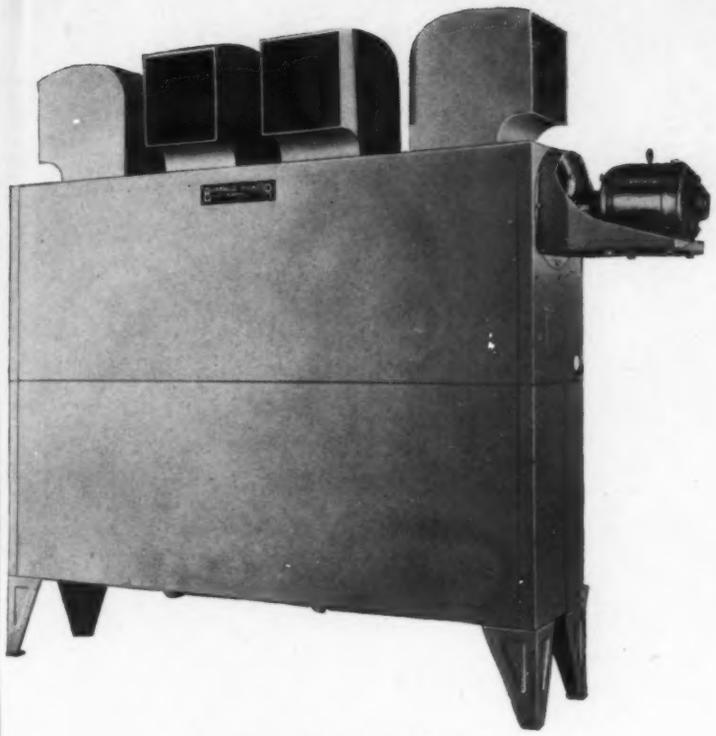

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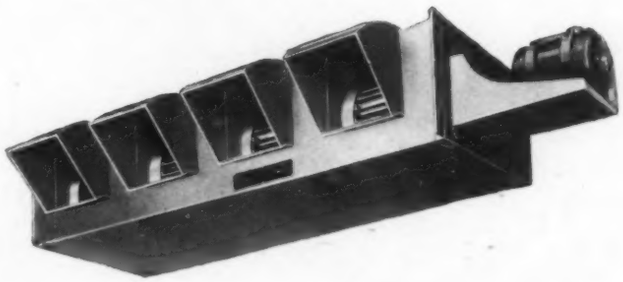


Lowboy Heaters are suitable for wall or ceiling mounting, same high efficiency as Highboys.

Write today for Bulletin 3134-A on Highboys and Lowboys, and Bulletin 3137-C on Breezo-fin Heaters, if you have a heating problem coming up.

NOT NEW!

The Buffalo Unit Heaters shown here are all pre-war models. They were designed in the beginning for industrial service, and so far, we haven't seen anything better for that service. Highboys, Lowboys and Breezo-fins — all are in use all over the country — giving efficient, economical heating in factories, warehouses, stores and offices.

NOT RADICAL!

About the design of these units — there's nothing that can be considered a radical innovation. We just draw the air over some copper finned steam coils, good for pressure up to 200 lbs., and deliver it, by means of quiet Buffalo fans, right where you need it. Because the fans and coils are efficient, you get economical heating.

NOT UNIQUE!

There are no "super-gadgets" on Buffalo Unit Heaters. The casings are heavy enough to withstand the handling and usage they can expect, without denting. Ball bearings are amply large, as are fan shafts. Fan rotors are dynamically balanced for continuous quiet operation.

PRACTICAL!

Buffalo Highboy and Lowboy Heaters are made in a complete range of practical sizes, to fit industrial requirements. They may be used as floor-type units, mounted upright on walls or girders, flat suspended under the roof, or suspended inverted. Because the fans will deliver air against duct-resistance, one unit can be used to heat several rooms. Full automatic controls are available for all models.

TIME TESTED!

Some of the largest industrial plants in the world are heated with Buffalo Unit Heaters. Because we build all our equipment for "extra-duty" service, you'll find that units ten, fifteen, even twenty years old are still on the job.

BUFFALO FORGE COMPANY

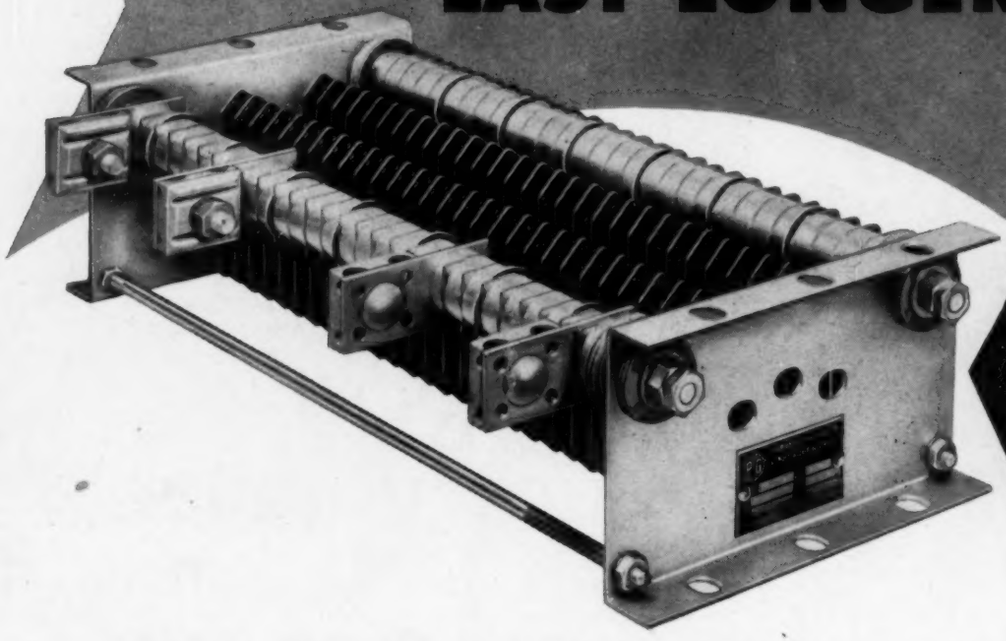
173 MORTIMER STREET **BUFFALO, NEW YORK**

CANADIAN BLOWER & FORGE CO., LTD., KITCHENER, ONT.

"Buffalo"

HIGHBOY & LOWBOY UNIT HEATERS

P-G *Steel Grid Resistors* LAST LONGER...



. . . GIVE BETTER PERFORMANCE WITH LESS MAINTENANCE!

Constructed from Steel and Mica (durable and non-breakable materials), P-G Steel Grid Resistors are truly built to last longer. Designed to efficiently use the space available, the utmost in long and trouble-free service can be expected. Try P-G Steel Grid Resistors next time on your toughest job . . . they are rugged . . . they are dependable.

Give us your specifications . . .

A P-G engineer can help solve your Resistor problem.

P-G

The Nonbreakable Steel Grid Resistor

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI 2, OHIO

He gives bearings a rub-down to put curves in the right places

. . . for faster operation, greater accuracy, maximum load capacity

IN the final manufacturing process, Timken T-type thrust bearings are assembled and processed so that the surfaces of the ribs, rollers and races are generated as a unit. The bearing thus becomes a "Generated Unit Assembly".

This extra process produces a smoothly-curved area of contact between the end of each roller and the cone rib against which it operates, so that the convex shape of the roll end and the concave surface of the cone ribs are identical in contour.

We developed this process years ago for thrust bearings which must operate under extreme loads with high roll and pressures against the cone ribs end since have adapted it to other Timken bearings, including those used for precision machine tools, steel mill and railroad equipment and other applications.

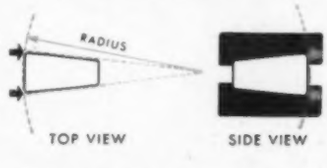
Today "Generated Unit Assembly" reduces friction and wear to the vanishing point; increases load capacity; assures positive roll alignment; eliminates the need of breaking-in or final adjustment on the job; and lengthens bearing life. It is one of the many reasons why it pays to have Timken bearings in every machine you manufacture or buy.

REMEMBER, Timken bearings are produced by the only bearing manufacturer in the country making its own steel and Timken is the acknowledged leader in: 1. advanced design; 2. precision manufacture; 3. rigid quality control; 4. special analysis steels. The Timken Roller Bearing Company, Canton 6, Ohio.

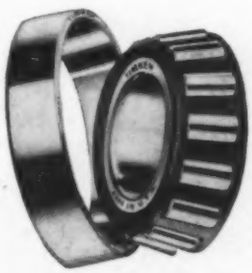
GENERATED UNIT ASSEMBLY

Extra manufacturing process makes Timken heavy duty thrust bearing a "Generated Unit Assembly".

CURVED AREA RIB CONTACT



Curved area of roll end (at arrows) fits perfectly the curve of upper and lower ribs of this thrust bearing.



TIMKEN

TRADE MARK REG. U.S. PAT. OFF.

TAPERED ROLLER BEARINGS

NOT JUST A BALL ○ NOT JUST A ROLLER ⊂⊃ THE TIMKEN TAPERED ROLLER ⊂⊃ BEARING TAKES RADIAL ◎ AND THRUST —◎— LOADS OR ANY COMBINATION —◎—

WHERE TO BUY

EQUIPMENT FOR SALE

POSITIONS VACANT

POSITIONS WANTED

THE ENGINEERING MART

AN *IRON and STEEL ENGINEER* SERVICE TO THE STEEL MILL OPERATORS

WHERE TO BUY

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Sales Representative
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BUFFALO 3, NEW YORK
Phone: WA 5459
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Reliance Electric & Engineering Co.
Railway & Industrial Engineering Co.
Pelham Electric Manufacturing Company

CHICAGO DISTRICT

PAUL W. WENDT & SONS
Manhattan Building
CHICAGO 5, ILLINOIS
District Representatives for
A. W. CADMAN MFG. CO.
HUNTER SAW & MACHINE CO.
GRAFO COLLOIDS CO.

E. A. SCHMIDT CO.
333 North Michigan Avenue
CHICAGO 1, ILLINOIS
Phone: State 6134
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Representing:
I-T-E CIRCUIT BREAKER CO.

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Phone: Wabash 4146-7
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Clark Controller Company
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(Air Preheaters)
For application to soaking pits, heating, and other types of metallurgical furnaces.
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All displayed classified advertising is sold in multiples of one inch at the flat rate of $8.00 per column inch. Minimum insertion is one inch. Maximum insertion is one column, 10 inches deep, or two columns, 5 inches deep.
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1010 Empire Building
PITTSBURGH 22, PENNSYLVANIA

PITTSBURGH (Continued)

PENNELL ASSOCIATES
Complete Material Handling Systems
O. R. Heidenrich
Investment Building
PITTSBURGH 22, PA.
ATlantic 6734
ELWELL-PARKER ELECTRIC CO.
Electric Industrial Trucks
NUTTING TRUCK AND CASTER CO.
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Union Trust Building
PITTSBURGH, PA.
Phone: ATlantic 1535

ROBERT E. BROWN CO.
Room 412, Jones Law Building
Pittsburgh, Pa.
ATlantic 2142
Representing electrical manufacturers to Pittsburgh industry.

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All displayed classified advertising is sold in multiples of one inch at the flat rate of $8.00 per column inch. Minimum insertion is one inch. Maximum insertion is one column, 10 inches deep, or two columns, 5 inches deep.
Deadline:
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THE ENGINEERING MART

PITTSBURGH (Continued)

PATTERSON-EMERSON-COMSTOCK, INC.

ENGINEERS AND CONSTRUCTORS

Specializing in Steel Mill Construction

313 E. Carson Street

Pittsburgh 19, Pa.

Phone: EVerglade 9800

W. G. KERR CO.

520 Oliver Building PITTSBURGH, PA.

Foote Brothers — Gears and Speed Reducers
Reeves Variable Speed Drives
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Telsmith Crushers
Phone: ATlantic 4254

ROLLING MILLS and EQUIPMENT

FRANK B. FOSTER

2217 OLIVER BUILDING PITTSBURGH 22, PA.

Cable Address "FOSTER" Pittsburgh

BUSINESS OPPORTUNITIES

OPPORTUNITY.....

knocks every month in The Engineering Mart section of the Iron and Steel Engineer. Take advantage of our low display classified rates. $8.00 per inch.

POSITIONS VACANT

WANTED

Sales representatives in Pittsburgh, Texas and West Coast districts for well known line of custom-built industrial furnaces. Attractive straight commission basis. IRON AND STEEL ENGINEER, Box 800, 1010 Empire Building, Pittsburgh, Pennsylvania.

POSITIONS VACANT—(Continued)

MECHANICAL ENGINEERS, DESIGNERS AND CHECKERS

Opportunities for experienced men with established manufacturing concern specializing in strip and wire mill machinery. State age, experience, education and salary earned and desired. Address IRON AND STEEL ENGINEER, Box 801, 1010 Empire Building, Pittsburgh, Pennsylvania.

SALES ENGINEER to represent large manufacturer of special ball and roller bearings in Pittsburgh area. Principal sales to machinery manufacturers and steel mills. Prefer engineer with steel mill experience. Address Box 802, Iron and Steel Engineer, 1010 Empire Building, Pittsburgh 22, Pennsylvania.

POSITIONS WANTED

ENGINEER — mechanical, college graduate, 25 years design experience steel plant equipment and plant development. Five years chief engineer. Practical, resourceful. Organizer. Excellent record and references. Employed, desires responsible position, domestic or foreign. Box 803, Iron and Steel Engineer, 1010 Empire Building, Pittsburgh 22, Pennsylvania.

ENGINEER with 25 years general steel mill experience including power plant design (7 years chief draftsman and assistant chief engineer) desires engagement in Cleveland district. State registered engineer. IRON AND STEEL ENGINEER, Box 804, 1010 Empire Building, Pittsburgh 22, Pennsylvania.

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All undisplayed classified advertising is sold at the rate of $1.00 per line. Five line minimum insertion charge. A box number address counts as one line.

Deadline:

All copy must be received by the 20th of the month preceding publication date.

IRON AND STEEL ENGINEER
1010 EMPIRE BUILDING
PITTSBURGH 22, PA.

WANTED

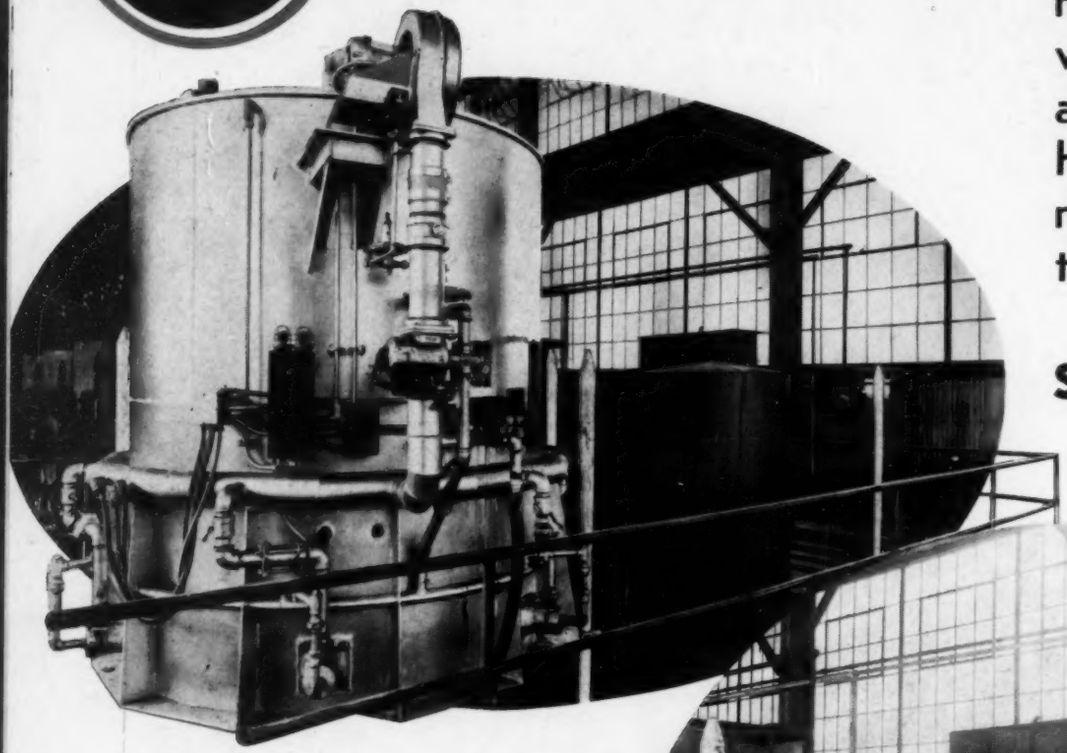
Copies of . . .
"THE MODERN STRIP MILL"
published by the AISE. If your copy is not being used why not sell it?

For details write
IRON AND STEEL ENGINEER
BOX 805
1010 EMPIRE BUILDING
Pittsburgh 22, Pennsylvania

The WILSON SINGLE STACK RADIANT CONVECTOR FURNACE

makes double wrapping of coils and higher piling heights an economic success for the

NARROW STRIP MILL



This Wilson Single Stack Furnace at Detroit Steel Corporation anneals 18 Tons of double wrapped strip coils piled 96" high in 12 hours furnace time—1½ Tons per Furnace Hour.

ENGINEERED AND CONSTRUCTED BY THE

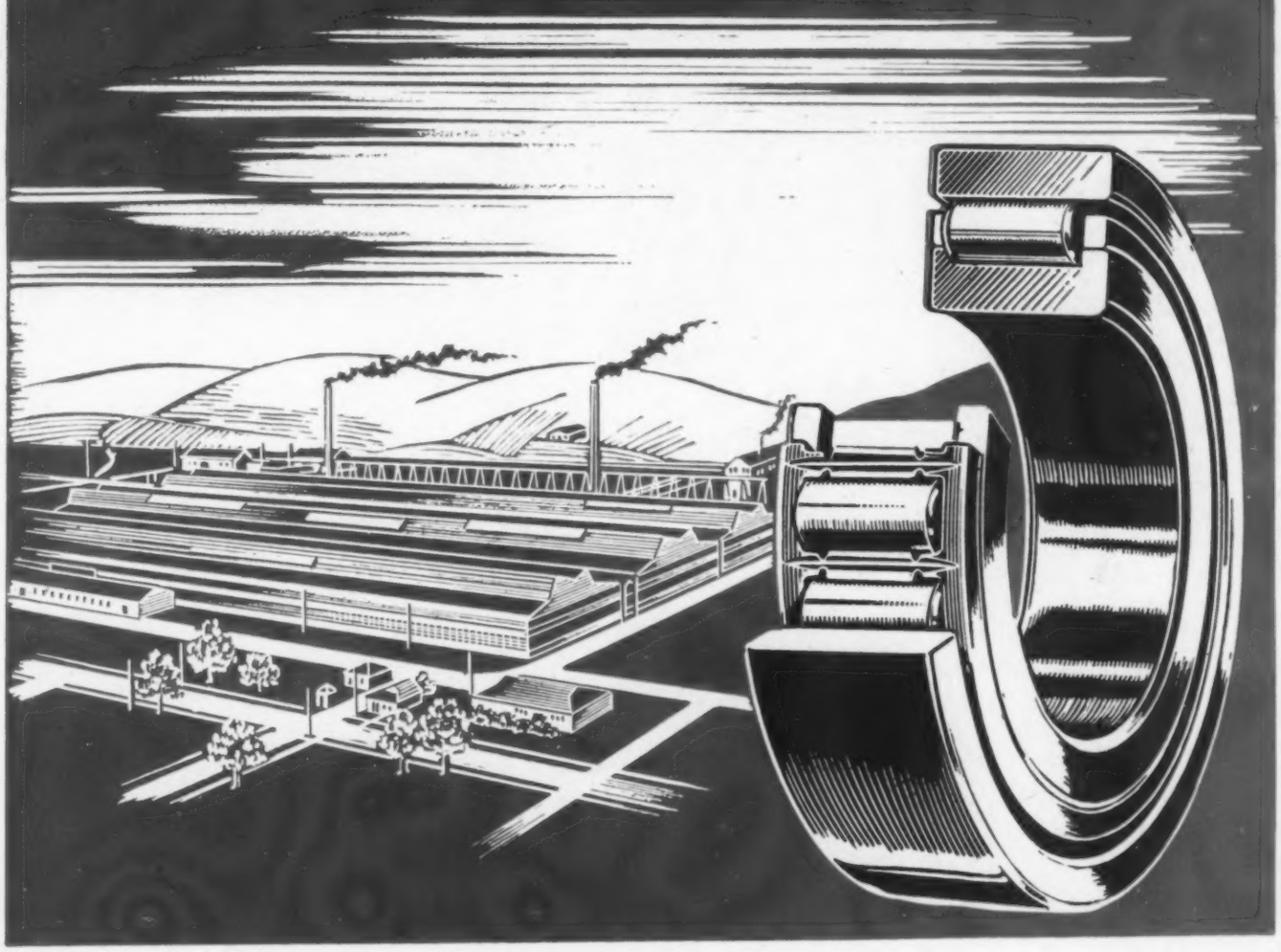
Lee Wilson ENGINEERING CO., Inc.

20005 West Lake Road CLEVELAND, OHIO

Telephone ACademy 4670

INDUSTRIAL FURNACES
RADIANT TUBE HEATING
HEAT TREATING PROCESSES

MAKE TYCOL ENGINEERED LUBRICATION A WORKING PARTNER



for increased production...lower operating costs

TYCOL
INDUSTRIAL LUBRICANTS

**Boston • Charlotte, N. C.
Chicago • Detroit
Pittsburgh • Philadelphia
Tulsa**

TIDE WATER ASSOCIATED OIL COMPANY
17 BATTERY PLACE · NEW YORK 4, N. Y.

For increased production . . . top efficiency . . . lower operating cost, give your machines superb lubricants – Tycol *Engineered* oils and greases. Tycol lubricants are made to meet every lubrication need of industry – from roll neck greases for steel mills to spindle oils.

Each Tycol lubricant is *scientifically engineered* to meet specific service conditions. In every step, from selection of crudes to blending of the finished product, Tycol lubricants are processed to provide maximum lubricating efficiency which means greater economy, longer machine life for every type of equipment.

Tide Water Associated engineers are thoroughly experienced in all phases of industrial lubrication. Let them help you in selecting the Tycol lubricant best suited to your specific need. Write, or wire your nearest Tide Water Associated Office for complete information.

LUBRICATION—"ENGINEERED TO FIT THE JOB"

BLAST FURNACES

1. BLOWER CONTROL
   - (a) Volume basis
   - (b) Constant weight basis
   - (c) Pressure and temperature compensated flow meters
2. GAS BLEED CONTROL
   - (a) Low differential metering
3. GAS DISTRIBUTION METERING
4. BLAST FURNACE STOVE CONTROL
   - (a) Gas input
   - (b) Gas-air ratio
   - (c) Stove dome temperature

Controls and Meters by

HAGAN

everywhere in the

STEEL INDUSTRY

BESSEMER

1. AIR FLOW OR AIR PRESSURE CONTROL
   - (a) Flow meters

BOILER HOUSES

1. STEAM PRESSURE REGULATION
2. LOAD DISTRIBUTION
3. FUEL-AIR RATIO CONTROL
4. FURNACE DRAFT REGULATION
5. AUTOMATIC FUEL MAKE-UP CONTROL
6. STEAM AND WATER DISTRIBUTION METERING AND CONTROL

COKE OVENS

1. EXHAUSTER CONTROLS
2. COLLECTING MAIN PRESSURE REGULATORS
3. STACK DRAFT CONTROL
4. UNDERFIRING GAS PRESSURE REGULATORS
5. MILLIMETER GAGES
6. FLOW RECORDERS

OPEN HEARTH AND HEATING FURNACES

1. HEAT INPUT CONTROL
2. ROOF TEMPERATURE CONTROL
3. FURNACE PRESSURE CONTROL
4. FUEL-AIR RATIO CONTROL
   - (a) Oil firing
   - (b) Gas firing
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6. DRAFT AND PRESSURE RECORDERS
7. FLOW METERS
8. B. t. u. METERS (Mixed for Firing)

SOAKING PITS

1. TEMPERATURE CONTROL
2. FUEL-AIR RATIO CONTROL
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   - (b) Gas firing
3. FURNACE PRESSURE CONTROL
4. GAS PRESSURE CONTROL

HEATING FURNACES

1. HEAT INPUT CONTROL
2. FUEL-AIR RATIO CONTROL
   - (a) Oil firing
   - (b) Gas firing
3. FURNACE PRESSURE CONTROL
4. GAS PRESSURE CONTROL

GAS DISTRIBUTION SYSTEMS

1. GAS PRESSURE REGULATION
2. MIXING STATIONS
3. SEQUENTIAL DISTRIBUTION CONTROL
4. PRESSURE STABILIZATION CONTROL
5. BLEED CONTROL
6. GAS FLOW METERS

HAGAN CORPORATION
Hagan Building
Pittsburgh 30, Pa.

HAGAN CORPORATION

HAGAN
HALL
BUROMIN
CALGON

METALLURGICAL FURNACE CONTROL SYSTEMS
RING BALANCE FLOW AND PRESSURE INSTRUMENTS
BOILER COMBUSTION CONTROL SYSTEMS

All piping equipment . . . All pre-fabrication . . . on One Order to CRANE

ONE
SOURCE OF SUPPLY
RESPONSIBILITY
STANDARD OF QUALITY

Pipe fabrication of every sort is Crane Co.'s business. From a simple bend to the most complex welded assembly, your design is assured of precise fabrication. Fully equipped, skillfully manned and strategically located, five Crane Pipe Shops are at your service.

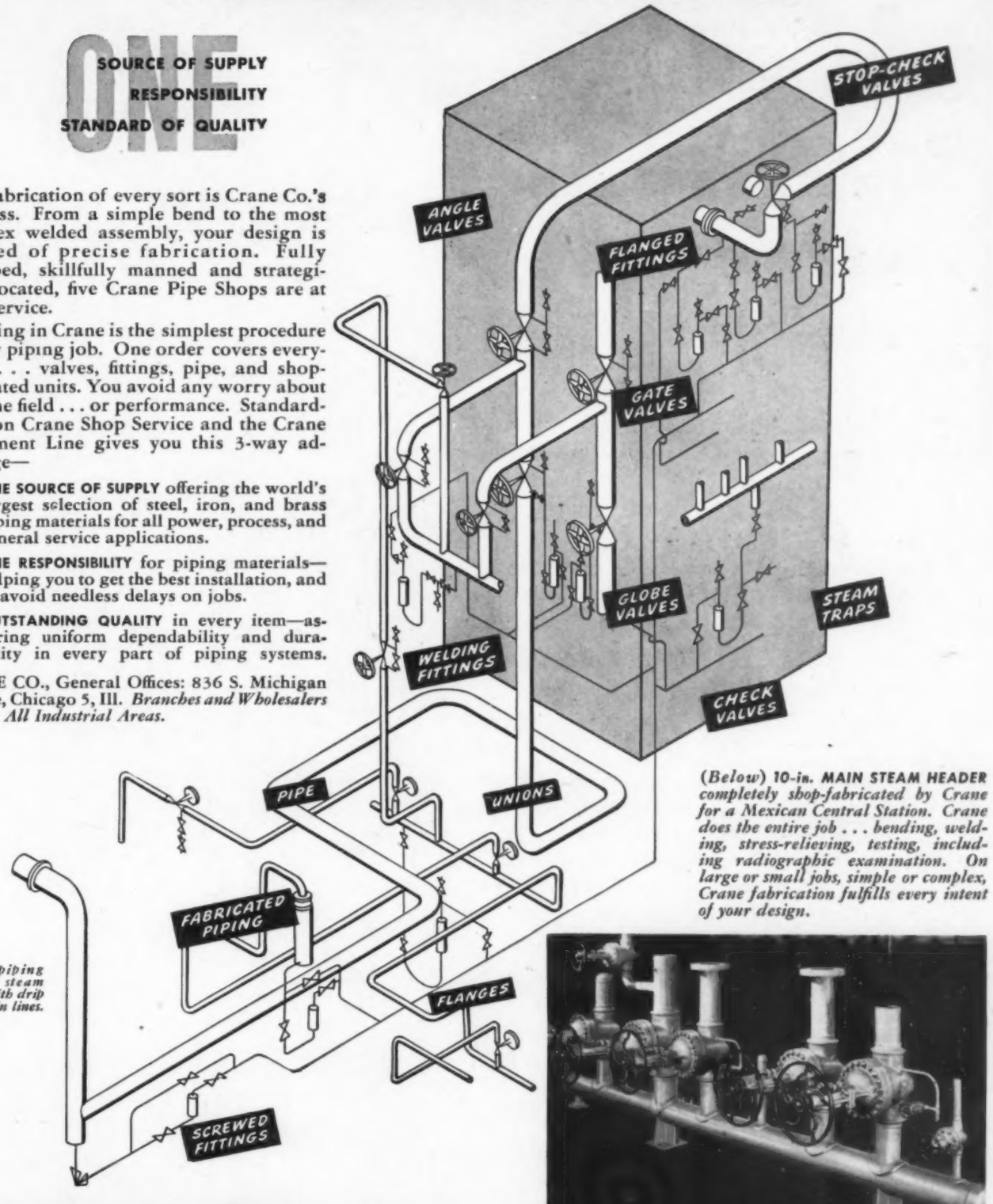
Calling in Crane is the simplest procedure on any piping job. One order covers everything . . . valves, fittings, pipe, and shop-fabricated units. You avoid any worry about fit in the field . . . or performance. Standardizing on Crane Shop Service and the Crane Equipment Line gives you this 3-way advantage—

ONE SOURCE OF SUPPLY offering the world's largest selection of steel, iron, and brass piping materials for all power, process, and general service applications.

ONE RESPONSIBILITY for piping materials—helping you to get the best installation, and to avoid needless delays on jobs.

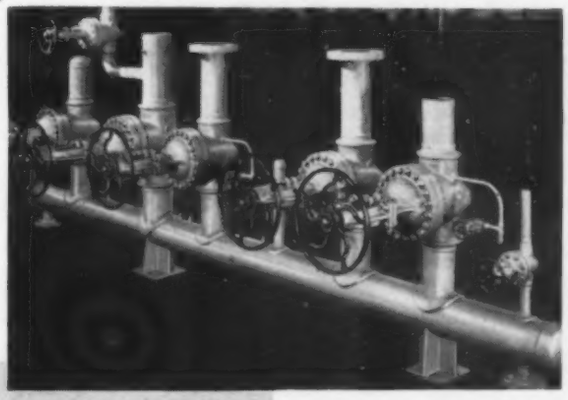
OUTSTANDING QUALITY in every item—assuring uniform dependability and durability in every part of piping systems.

CRANE CO., General Offices: 836 S. Michigan Avenue, Chicago 5, Ill. *Branches and Wholesalers Serving All Industrial Areas.*



Boiler piping showing steam mains with drip and drain lines.

(*Below*) **10-in. MAIN STEAM HEADER** *completely shop-fabricated by Crane for a Mexican Central Station. Crane does the entire job . . . bending, welding, stress-relieving, testing, including radiographic examination. On large or small jobs, simple or complex, Crane fabrication fulfills every intent of your design.*



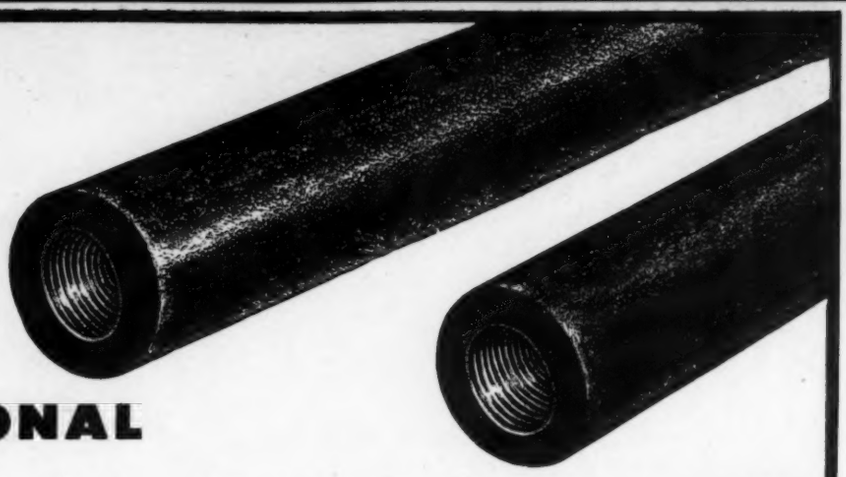
EVERYTHING FROM . . .

VALVES • FITTINGS
PIPE • PLUMBING
AND HEATING

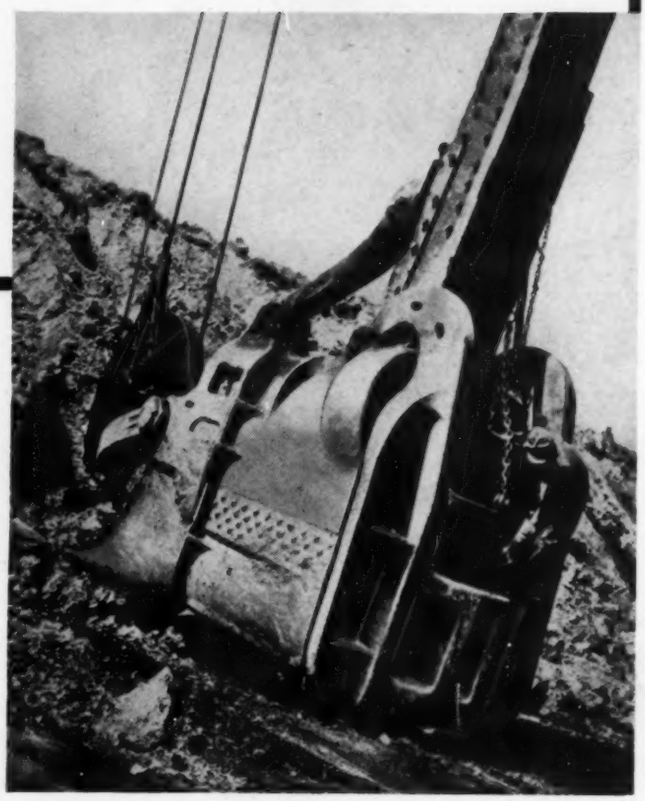
CRANE

FOR EVERY PIPING SYSTEM

Back of the shovels that move mountains



INTERNATIONAL GRAPHITE ELECTRODES



The tough, hard-working steels used in mining and quarrying equipment to combat the relentless attack of hard, abrasive rock often outlast ordinary steels 10-to-1.

Makers of heavy-duty castings used in earth-moving machines—dipper teeth, bucket chains, crawler and conveyor parts—are regular users of International Graphite Electrodes.

In their products there can be no compromise with quality. And they have found, in actual electric furnace operation under a wide range of production requirements, that International Electrodes have what it takes to make the steels that can "take it"—the right physical, electrical and chemical properties in the right combination for their exacting needs.

For all-around satisfaction and economical performance, specify International the next time you buy electrodes. Write for details and prices today.

Specify INTERNATIONAL Graphite Electrodes for—Slow consumption—High current capacity—Low rate of oxidation—High thermal conductivity—High degree of purity—Consistently uniform properties and dimensions—Low cost per ton of production.

IGE

International Graphite & Electrode Corp.

SAINT MARYS, PA.

2547

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Wickwire Division
Colorado Fuel & Iron Corporation
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Duquesne Works
Carnegie-Illinois Steel Corporation
Duquesne, Pennsylvania

J. L. HYLAND
District Manager
Republic Steel Corporation
Cleveland, Ohio

GEARY E. KAMERER
Assistant Chief, Electrical Department
Wickwire-Spencer Steel Division
Colorado Fuel & Iron Corporation
Buffalo, New York

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Bloom and Billet Mills
Steel Company of Canada, Ltd.
Hamilton Works
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Dorman, Long & Company, Ltd.
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EARL G. LINDSAY
Roll Shop Turn Foreman
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CHARLES E. MILLER
Packaging and Loading Engineer
Carnegie-Illinois Steel Corporation
Pittsburgh, Pennsylvania

J. EVAN MORGAN
Assistant Packaging and Loading Engineer
Carnegie-Illinois Steel Corporation
Pittsburgh, Pennsylvania

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Assistant Superintendent
Gautier Department
Bethlehem Steel Company
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WILLIAM HUMPHREY NORTH
Linthorpe
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M. ROSS PHILIPS, JR.
Manager of Orders
Republic Steel Corporation
Southern District
Gadsden, Alabama

G. H. REARICK
Plant Superintendent
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Welded Tube Division
Alliance, Ohio

LEWIS J. REGULY
Chief Mechanical Draftsman
Inland Steel Company
East Chicago, Indiana

ALLEN ROBINSON
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Fuel, Power and Maintenance
American Steel & Wire Company
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National Tube Company
Ellwood Works
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FRANCIS J. YOUNG
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Mechanical Engineering Department
Carnegie-Illinois Steel Corporation
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Associate

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Metalock Casting Repair Service
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General Electric Company
Schenectady, New York

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President
Amer-Ind. Inc.
New York, New York

C. R. MCCLOSKEY
Sales Engineer
Salem Engineering Company
Salem, Ohio

B. H. MCDANIEL
Development Engineer
Dowell, Incorporated
Philadelphia, Pennsylvania

DAVID MACHEMER
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Birdsboro Steel Foundry and Machine Co.
Birdsboro, Pennsylvania

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Brown Instrument Company
Detroit, Michigan

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Engineer
Giffels and Vallet, Inc.
Detroit, Michigan

WILLIAM P. BLEIL
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Aerovent Fan Company
Detroit, Michigan

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Thomas A. Edison, Inc.
Edison Storage Battery Division
West Orange, New Jersey

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Sales Engineer
English Electric Company of Canada, Ltd
St. Catherines, Ontario, Canada

JULIAN D. CALE
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Ohio Electric Manufacturing Company
Cleveland, Ohio

FLETCHER B. CARNEY
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Industrial Division
Timken Roller Bearing Company
Birmingham, Alabama

R. M. CARSON
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Westinghouse Electric Corporation
San Francisco, California

RAY B. CONKLIN
Associate District Manager
Dollinger Corporation
Buffalo, New York

L. D. CULP
Field Engineer
Leeds and Northrup Company
Philadelphia, Pennsylvania

GLEN H. DEWEY
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General Electric Company
Buffalo, New York

JAMES G. DRUMM
Sales Engineer
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Dearborn, Michigan

ARNOLD DUNN
President
Dearborn Industrial Engineering Company
Dearborn, Michigan

LEW DURDIN
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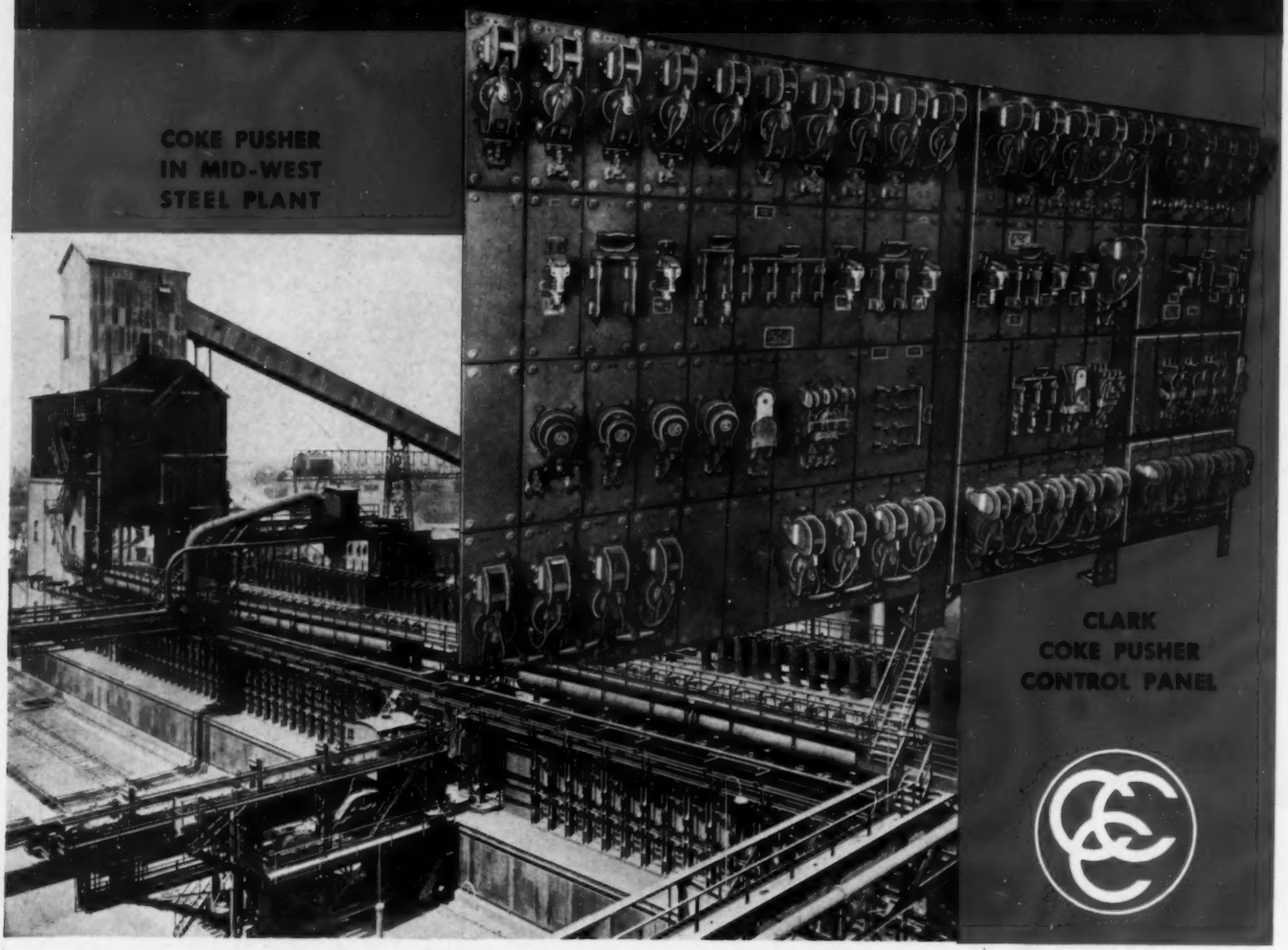
CLARK CONTROL HANDLES HEAVY-DUTY COKE PUSHER JOB SUCCESSFULLY



COKE PUSHER IN MID-WEST STEEL PLANT

CLARK COKE PUSHER CONTROL PANEL

● This Clark Coke Pusher Control Panel controls and protects 2—55 HP Bridge Motors, 1—55 HP Pusher Ram Motor, and 1—35 HP Leveler Bar Motor. Another Clark Control Panel (not shown) is used with motors for the Door Extractor Ram, Door Extractor Hook, and Door Extractor Mud Box.

As the panel is subject to considerable vibration and shock, particularly when the Pusher Ram has to batter away at impacted coke, each piece of Clark apparatus is mounted upon a separate panel. Each of these panels in turn is mounted on an angle iron frame.

Clark Bulletin 7400 Vari-Time Contactors and Bulletin 7313 Vari-Time Relays, both of which have built into them the property of delaying for an adjustable definite time—after their coils are energized—the closing of its main contacts. This patented Vari-Time feature eases the starting load on the motors, and cushions the shock of ram and batter action.

Wherever the going is tough in mill operations, there you'll find Clark Heavy Duty Control.

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1 **Costs are cut** with Laminated Plastic Bearings because these bearings customarily outwear metal bearings by several times. Impressive savings result from fewer shut-downs for bearing replacement. Costs are cut still further because . . .

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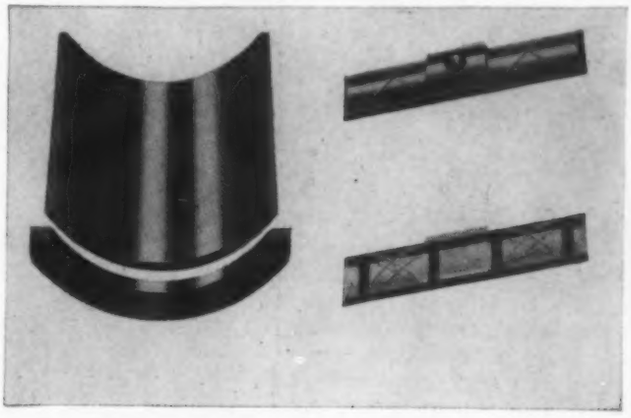

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5 For full information on A-B-K Laminated Plastic Bearings and their application to your steel mill bearing problems, communicate with American Brakeblok Division, 4600 Merritt Avenue, Detroit 9, Mich.

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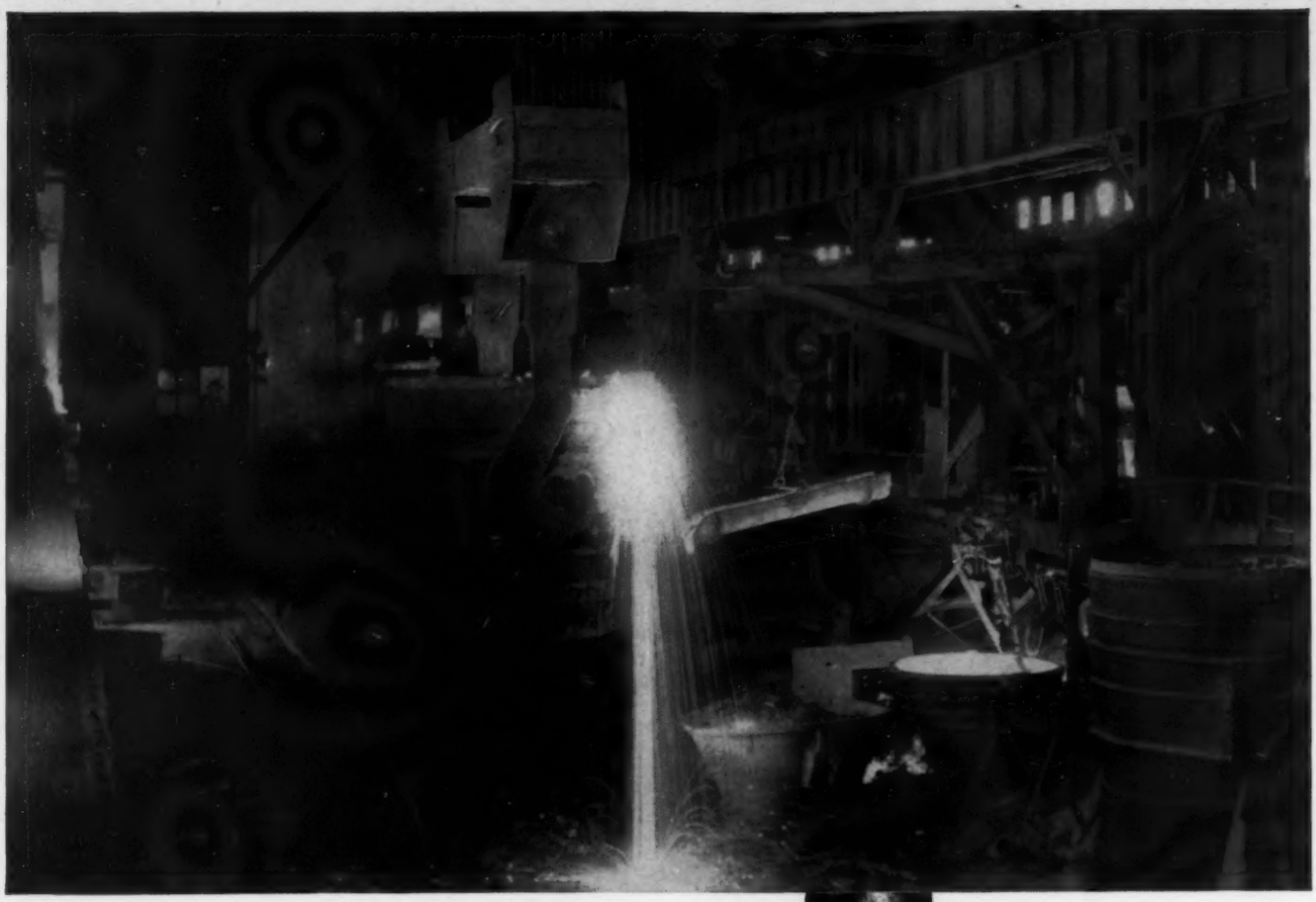
*A·B·K Laminated Plastic Bearings

AMERICAN Brake Shoe COMPANY — AMERICAN BRAKEBLOK DIVISION



It Pays its Way
IN THE WORST PLACES!

Hot steel and the processes required to make it a finished product set up just about the worst assortment of conditions wire and cable have to operate under. That's why you'll find Rockbestos A.V.C. *paying its way* in steel mills, foundries — and also in automotive, ceramic, petroleum and food processing industries and others where severe conditions make it tough for power, control and lighting circuits.

For a few of the reasons why Rockbestos A.V.C. *pays its way* in places where other wires carry a short life, read the panel to the right of the cable. Note that the insulation and braid are made of fibres of asbestos, an ageless, non-deteriorating, heat and flame resisting mineral that won't bake brittle, flow, crack or burn. And remember that it withstands operating temperatures up to 230° F. *continuously* and gives you a *plus* in greater current carrying capacity.

To reduce maintenance expense and protect operations, wire your worst circuits with Rockbestos A.V.C. or All-Asbestos wires and cables — 125 different types in 300 to 5000 volt ratings — single or multi-conductor, braided, lead sheathed or armored. Write for recommendations.

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199 Nicoll Street, New Haven 4, Conn.

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The Wire with Permanent Insulation

HERE'S THE "WHY" BEHIND LONGER SERVICE

Rockbestos A.V.C. 600 volt Power Cable and similarly insulated Motor Lead Cable (N.E. Code Type AVA) have a maximum operating temperature of 110° C., and this failure-preventing construction:

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One of 125 different constructions designed by Rockbestos for severe operating conditions in ratings up to 5000 volts.

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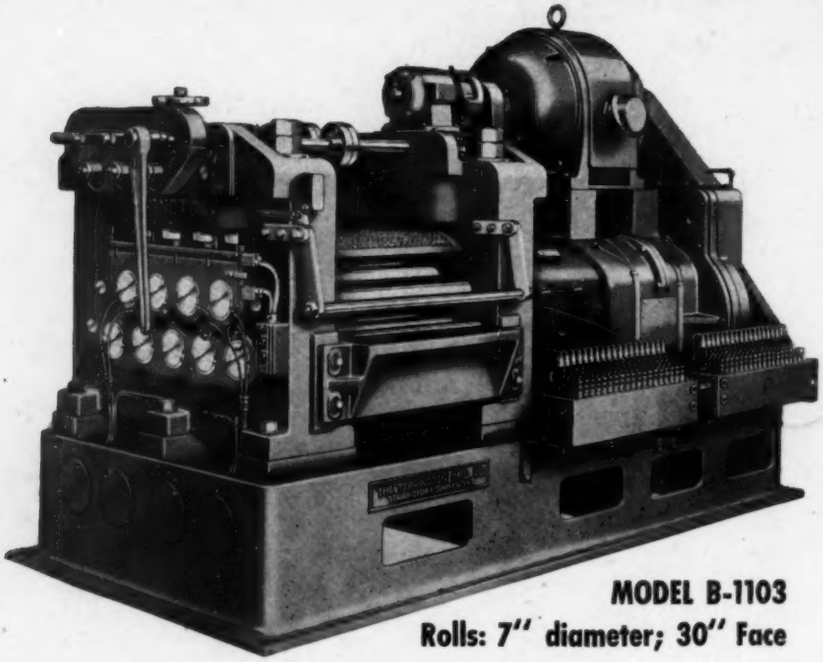
Another TORRINGTON *Special*



MODEL B-1103
Rolls: 7" diameter; 30" Face

FLATTENING MACHINES

These multi-roll machines are designed to remove the buckles and waves from slab, strip and sheet metal, producing it commercially flat. There are twelve standard models, varying in size, and special machines can be built to fit specific requirements. Standard models are 9 roll (5 lower, 4 upper) but can be built with 5, 7, 11, 19 or 23 rolls, if necessary. Also the machines may have feed rolls on one side or both sides.

FOR OVER 60 years, Torrington Manufacturing has been designing and building special machinery for processing sheet, strip, flat wire, rods and tubes, as well as air-cooled or water-cooled molds for casting copper-bearing alloys. Fine modern facilities include a highly trained design and engineering staff, pattern shop, forge shop, hardening room, welding shop, completely equipped machine shop, and large assembly floor covered by cranes. Experienced, skillful men work under ideal conditions. Our standard designs can be modified to meet special requirements and we work closely with customers' engineers in adapting machines or designing and building new machines. This collaboration assures special attention to maintenance and production problems.

Privacy is guaranteed when we build from customers' drawings or design and build under their supervision. Materials and workmanship are also guaranteed. Call or write Torrington Manufacturing with complete details of your requirements. We'll not only build a machine to suit your specifications, but will also help set it up and start it in production in your plant.

MODEL B-1103
FEATURES

CAPACITY: (Metal 30,000 lbs. P. S. I. tensile strength—24" wide.) Thickness: Minimum .312" to Maximum 1.000".
Length of rolls can be made to suit, within reasonable limits.

SPEED varies with horse power and specific conditions. 60 H. P. motor recommended for 100 ft. per min. metal speed at above metal specification.

ROLLS are interchangeable, all positively driven. Are of either unhardened alloy steel or special tool steel hardened to 60-63 Rockwell C range, as desired.

SPINDLES: Each roll is connected to its driving pinion by a spindle having flexible connections for ease of adjustment and to compensate for wear.

ADJUSTMENT: Each upper roll is adjustable in parallel, with provision for alignment. Mechanism for adjusting all upper rolls as a unit may be added. Indicators show degree of adjustment.

GUIDE TABLE at entry and exit and guard rolls on both sides.

DRIVE MOTOR is located over pinion housings, saving floor space, at right or left hand side of machine as desired. Drive from motor to pinions is through double helical gearing or chains and sprockets. No clutch required.

OTHER FEATURES: Roll housings capped for easy removal of upper rolls. Entire drive including spindles is enclosed. All bearings sleeve-type bronze.

The **TORRINGTON**
MANUFACTURING COMPANY
TORRINGTON, CONNECTICUT

As the white outline indicates, a standard unit of much greater frame size would be required to do the work of Speedaire.

SPEEDAIRE saves colliery $416

THIS Speedaire Unit drives a Refuse Drag Conveyor in a West Virginia coal tipple. It operates for two eight-hour shifts every day in a dusty atmosphere and saved the coal company $416.50. This is 35.6% under the cost of a conventional worm gear speed reducer required to do this job.

Speedaire is Cleveland's new fan-cooled worm-gear speed reducer. Because it is fan-cooled, Speedaire will do more work—will deliver up to *double the horsepower* of standard worm units of equal frame size, at usual motor speeds. It can be installed economically on many applications where other types have been used heretofore—giving you the advantage of a compact right-angle drive. Speedaire gives the same long, trouble-free service characteristic of all Clevelands.

For full description, send for Catalog 300 The Cleveland Worm & Gear Co., 3278 East 80th Street, Cleveland 4, Ohio.

Affiliate: The Farval Corporation, Centralized Systems of Lubrication. In Canada: Peacock Brothers Limited.

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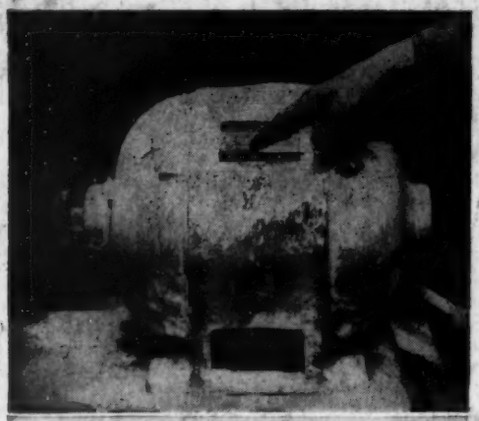
Worm Gear
Speed Reducers



ON 1,220,000 MOTORS

TRI CLAD

THE SYMBOL OF EXTRA PROTECTION

Keeps Its Bearings in "Dust Bowl"

Ordinarily, we wouldn't recommend that you use an open motor on a job like this. This Tri-Clad motor drives a boiler-feed pump in the National Gypsum Company plant at Clarence Center, N. Y. The air surrounding the motor is constantly filled with gypsum dust which must be kept out of the bearings. And it *has* been kept out of the bearings of this Tri-Clad motor, thanks to its specially designed bearing housing and seals. We believe that the Tri-Clad motor you see here proves that even where dust, moisture, or some other hazard is extremely severe for open-motor applications, the extra protection afforded by Tri-Clad motor construction results in longer motor life and lower upkeep.

The toughest motor yet!

The Tri-Clad totally enclosed, fan-cooled motor is designed for use in adverse atmospheres — in iron dust, out of doors, in hazardous areas, and chemical atmospheres. It gives you these important construction features:

- A cast-iron, double-wall frame which completely encloses and protects the windings and punchings.
- A nonshrinking compound around motor leads which protects motor interior from dust and moisture.
- A rotating labyrinth seal which further protects the motor interior from damage by foreign matter.

TRI CLAD
REG. U.S. PAT. OFF.
MOTORS

Announcement of the Tri-Clad motor, back in 1940, ushered in a new concept of general-purpose motor design. Substantially increased horsepower-per-frame-size was one feature. Smarter appearance was another. But what really sold more than a million Tri-Clad motors is the *extra protection* we built into them.

Today, with the "family" including dripproof motors, vertical motors, gear-motors, capacitor-motors, and totally enclosed motors, Tri-Clad motor is, more than ever, the motor that means basic protection, dependable performance, and minimum upkeep. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

***EXTRA PROTECTION*... AGAINST PHYSICAL DAMAGE!**

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Windings of Formex* wire together with improved insulating materials, reduce the chances of electrical failure. Heat is dissipated quickly — motor stays young for years and years.

***EXTRA PROTECTION*... AGAINST OPERATING WEAR AND TEAR!**

Bearing design affords longer life, greater capacity, improved lubrication features. Bearing seals retain lubricant, keep out dirt. One-piece, cast-aluminum rotor is practically indestructible.

**Trade-mark reg. U. S. Pat. Off.*

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